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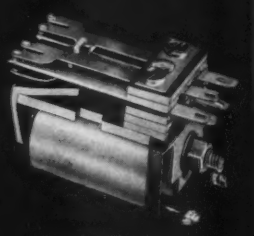

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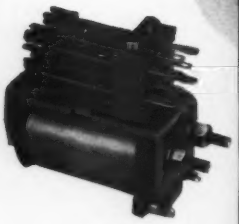

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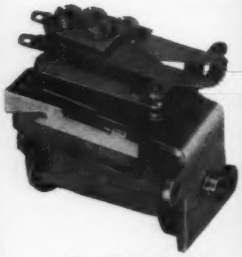

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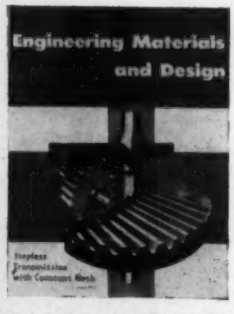

Artist's impression of the working principle of the stepless transmission with constant mesh described in this issue.

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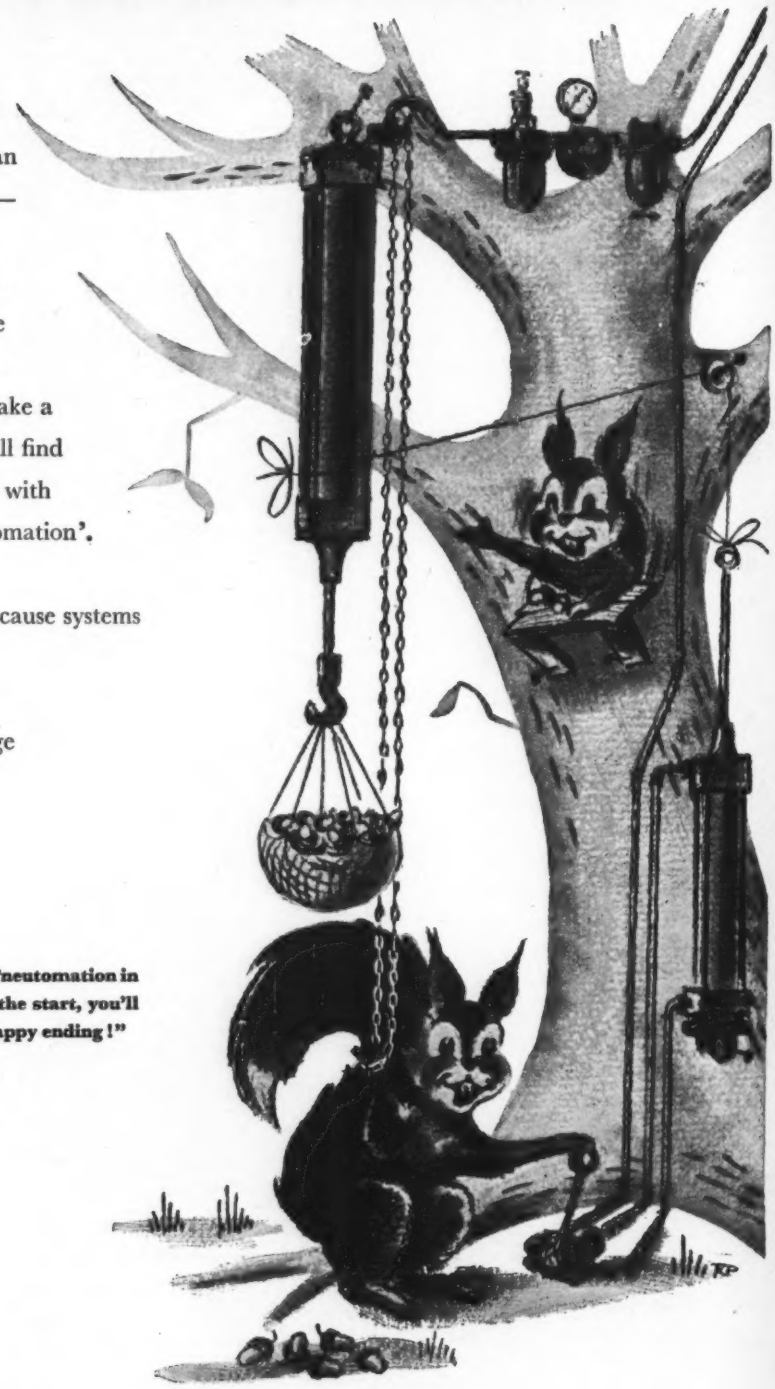

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MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Materials and Components Exhibition

THE FIRST EXHIBITION devoted entirely to materials and components is to be held at Earls Court, from February 22-26 next year. Sponsored by ENGINEERING MATERIALS AND DESIGN and organised by Industrial & Trade Fairs Ltd., the exhibition will serve a valuable function in enabling exhibitors to meet technical staff who are confronted with engineering problems and will enable engineering designers to keep abreast of the numerous materials and components available to them. A conference for engineering designers will be arranged to run concurrently with the exhibition and will be based on new developments and recent progress in a wide field of engineering materials and components. The theme of the conference will be the influence of materials and components on design; one session will be devoted to appearance design.

Ignition of Titanium

WIDELY USED in applications where chemical inertness is vital, titanium may have to be reappraised by some of its users following a discovery that the metal can ignite and continue to burn rapidly under certain conditions.

Like most metals, finely divided titanium will undergo oxidation, but solid pieces have been expected to remain stable. Recently, it was noted in the U.S.A. that a titanium valve in a test loop containing a hot, pressurised solution plus oxygen would sometimes be destroyed under normal operation; similar incidents have been reported in other centres.

An explanation of this has been produced at the Stanford Research Institute in California. Usually a thin, adherent coating of oxide protects titanium and prevents further oxidation; it was discovered, though, that depending on the pressure and the oxygen concentration, solid pieces of titanium would ignite and oxidise rapidly. The factor necessary to cause this was the exposure of a fresh, uncoated surface of the metal to oxygen as, for instance, when a solid piece of titanium was ruptured. Unexpectedly, once the oxidation was started it continued in atmosphere with much lower oxygen levels than were needed to initiate the process.

High-speed film of the reaction showed that the metal burned rapidly but very smoothly, confirming the belief that, as the oxides were formed on the fresh titanium surface, they did not coat the surface but were dissolved back into the interior of the metal where it was hot enough to be molten. A continually fresh surface was thus exposed to oxidation.

Structural Effects of Kinetic Heating

THE IMPORTANCE of materials selection is the design of high-speed aircraft was clearly expressed in two papers recently given at a discussion held by the Royal Aeronautical Society. Mr. W. G. Heath, of A. V. Roe Ltd., dealt mainly with currently available materials suitable for structures operating at temperatures up to 500 deg. C. and he also mentioned temperatures up to 1,000 deg. C. It was pointed out that structural efficiency cannot always be judged from a plot of mechanical properties against temperature and it is concluded that the only satisfactory method of selection is the simultaneous choice of material and type of structure. The speaker emphasised that the interaction of creep and fatigue phenomena was still largely unknown, and that for the present each should be considered separately. In considering metals for service at temperatures of 1,000 deg. C. it was noted that molybdenum oxidises easily, the oxide burning away when hot. When alloyed with titanium, this metal, at 1,000 deg. C., has a good specific stiffness but low buckling stability and poor creep resistance. The principal factors affecting design are likely to remain availability and formability of the material chosen.

In the paper "Design of Transparencies" by Dr. J. S. Przemieniecki, of Bristol Aircraft Ltd., the effects of kinetic heating on supersonic aircraft were studied. In assessing materials for transparencies at high temperature, of prime importance is the thermal stress condition coupled with the fact that material properties usually deteriorate at high temperature. The strength of soda lime glass initially decreases as heating time and temperature increases, but above 150 deg. C. it is approximately independent of heating time and there is a slight increase with temperature. Similar results should be obtained for fused silica. It is considered that the latter is better than soda lime glass in high-temperature applications, since its coefficient of expansion is one-sixteenth that of glass and its conductivity is some fifty per cent greater. Young's Modulus for silica increases with temperature, while that of soda lime glass decreases. The problems of fail-safe design of transparencies are considerable, and it is suggested that windows would not be incorporated in the passenger cabin of supersonic aircraft. As well as removing the transparency problem, this would improve the structural efficiency of a pressure cabin. It is possible that the pilot's window would only be used for take-off and landing, a system of blinkers screening the windows during high-speed flight.

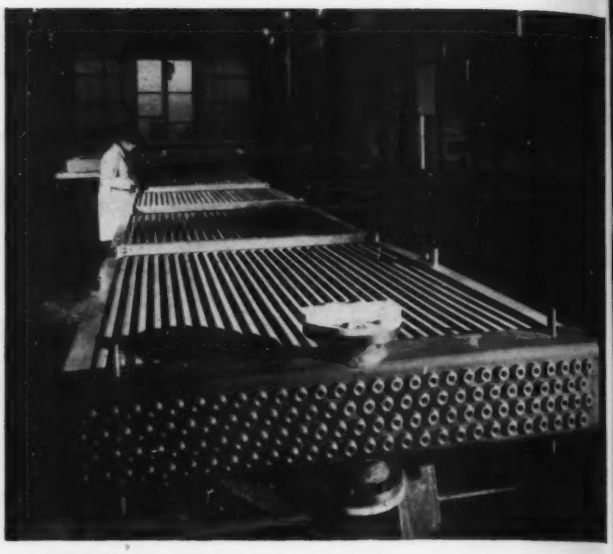
Forming by Explosives

THE USE OF EXPLOSIVES to form metal parts is not only because of the relatively cheap energy made available to supply a forming force, but because this method of shaping promises to give the designer greater scope in the shapes which can be produced or in the materials which can be used. Most metals show an improvement in mechanical properties when dynamically loaded. This means that, compared to a static stress-strain curve, the yield point, the ultimate and the fracture point are higher when the rate of loading is of the order of 500-2,000 f.p.s., as occurs during explosive forming. Aerojet-General have shown that it is therefore possible in this process to work right up against the fracture point, thereby making fullest use of the extended elongation obtained.

A process known as velocity impact hardening is also being developed by the Ryan Aeronautical Co., who are using explosives to impart strength and wear resistance to metal. It is claimed that steel can be work hardened by explosives without the deformation which occurs during pressing or hammering and that deeper hardening results. A special flexible explosive sheet has been developed by Du Pont so that it can be easily formed and shaped, but retains safe explosive properties. The sheet can be cut with a knife and formed by hand to the surface to be hardened. It is believed that the shock wave transforms soft ductile austenitic steel, by stressing it, into a strong, tough and wear-resistant material, which is indistinguishable from normal cold-worked steel.

SELF-RIGHTING PLASTICS LIFE-BOAT ▼

A new type of self-righting life-boat with the looks of a submarine has just been demonstrated in Germany. Designed by Gustav Kuhr, it has walls made of glass fibre-reinforced polyester and hard p.v.c. foam in sandwich form. It has four hatchways that can be hermetically sealed to exclude all water. There is a bubble window to facilitate observation without the need to open hatches. (Photo: Reichhold Chemicals Inc.)

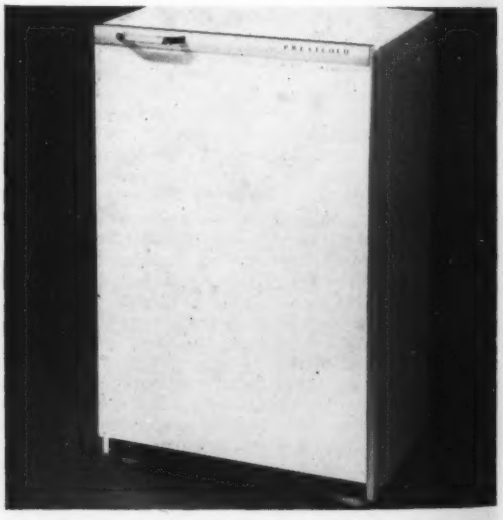


THREE MILES OF TUBING ▲

Three miles of carbon steel tubing were used in each of the air blast coolers recently completed by Spiro-Gills Ltd. for the Kuwait Oil Co.'s first natural-gas injection plant, which will deal with 86 million cubic feet of gas daily. The tubes, arranged in three sections, are wound with flat helical aluminium gills, to give a total surface area of 72,600 sq. ft. One of the completed coolers is seen here.

PICTURE NEWS

IN THE WORLD OF MATERIALS & DESIGN

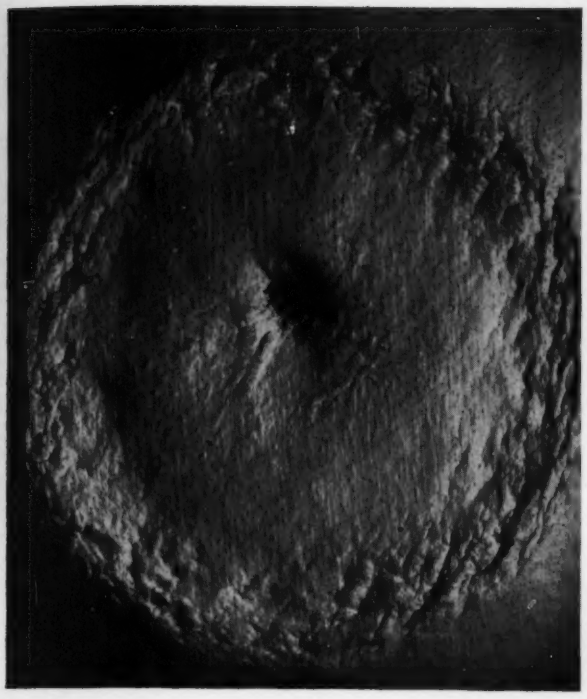


SIMPLICITY EARNS AWARD ▲

The Packaway refrigerator, one of the sixteen products chosen by the Council of Industrial Design for its "Design of the Year" awards, has also been selected for the Duke of Edinburgh prize for elegant design. This was designed by Mr. C. W. F. Longman, of the engineering department of Prestcold, in association with Edward H. Wilkes, consultant industrial designer. Apart from its positive features, the judges were impressed by the absence of self-conscious streamlining and styling.

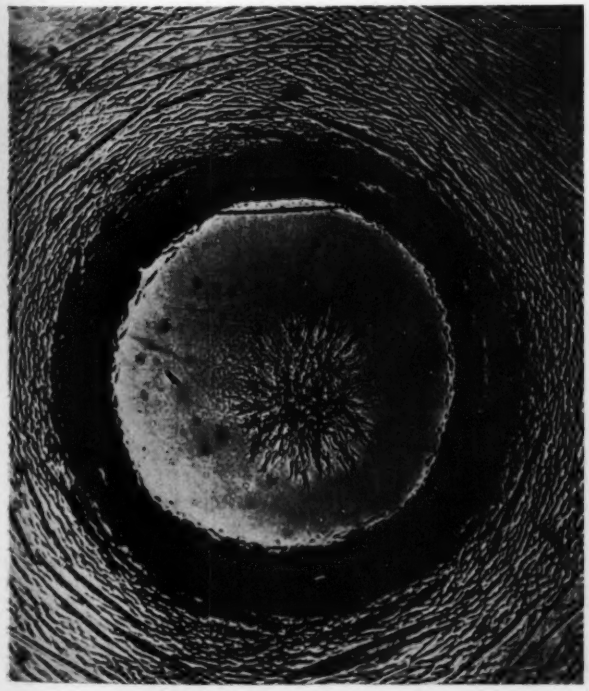
BRUSHES AND SLIP RINGS ELIMINATED ◀

Slip rings and brushes are replaced on this alternator by silicon diodes which are fitted to the rotor. The diodes rectify the exciter output and feed d.c. into the rotating field by a permanent connection. Advantages of this arrangement—a development by Electric Machinery Mfg. Co. of U.S.A.—are reduced maintenance and fire hazard. It is also expected to give substantial manufacturing cost reduction.



RAIN LIKE BULLETS ▲ ▼

These two pictures taken at the Cavendish Laboratory, Cambridge, show the surface damage caused by a drop of water striking (above) a stainless-steel sheet and (below) Perspex sheet. Under simulated conditions, they indicate the effect of an ordinary raindrop colliding with parts of high-speed aircraft. The water drop weighs 0·01 gm. and strikes the surface at 760 metres/sec. In the case of the Perspex, the central surface is undamaged, and fracture is actually below the surface. Even a rubber struck at very high speeds may be shattered like glass.



EXPANDING NON-FERROUS RESEARCH

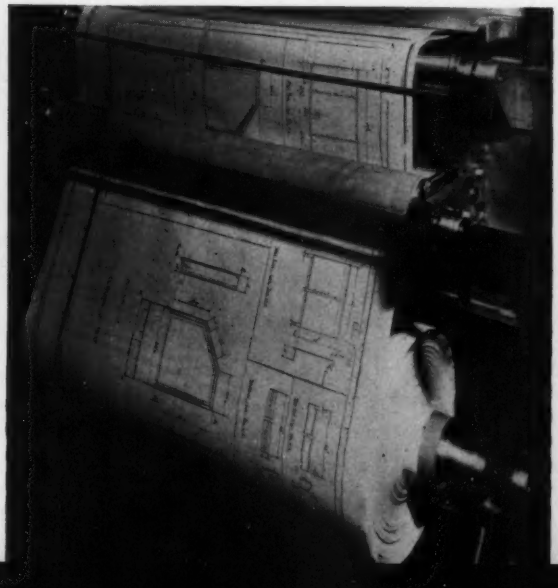
The British Non-Ferrous Metals Research Association has recently opened a new laboratory block. Alloying is carried out there by melting in an arc furnace in an atmosphere of argon. The one illustrated was built in the workshops some time ago when the technique was comparatively new.

TWO-THOU FLATNESS

Two angular contact ball bearings, of 8 ft. diameter, of the type shown here are being supplied by the Cooper Roller Bearings Co. for the Berkeley nuclear power station. Built to carry a load of 90 tons, each bearing supports the control rod and actuator servicing machine for a reactor. Bearing run-out and flatness is 0·002 in.

HIGH-SPEED REPRODUCTION

This is the new Rank-XeroX Copyflo printer, which can copy engineering drawings on to ordinary unsensitised paper at the rate of 20 ft. of prints a minute, printing continuously.



Light Alloys for Engines

WIDER USE of light alloys in automobile engines is reflected in their application by two British manufacturers. Light alloy is used for the exhaust manifold of the new Rootes horizontally-opposed two-stroke diesel-engined truck. This has been made possible by increased volumetric efficiency and exhaust gas scavenging, thus giving reduced outlet gas temperatures. Other components in this engine made of light alloy include the sump, rocker covers, flywheel and timing cases and the blower casing.

Another engine to make good use of light alloy is the new Daimler Dart, which has been launched initially in the U.S.A. and which has push rods and certain other components of light alloy.

Polyurethane Foams

BOTH RIGID and flexible forms of polyurethane foam are finding uses in widely differing fields of engineering. At the Salon de la Chimie being held in Paris from June 18-29, some of these uses, which include insulation for ships' deckheads, bulkheads and refrigerator holds, are being depicted by I.C.I. Dyestuffs Division, who pioneered their development in the U.K. An increasing use is also being found for the flexible foams in lagging pipes. Polyurethane foams, in addition to being strong and light, adhere firmly to many surfaces and an interesting feature is that steel plates backed with foam may be successfully welded because the foams are virtually non-inflammable.

Vacuum Melting for High Grade Steels

VACUUM MELTING is a technique that has been used increasingly in recent years for the production of high quality steels, titanium and zirconium. For the designer, these steels have not only improved strength characteristics, but also freedom from deleterious inclusions which might lead to premature failure of high-duty components. A further advantage is, for instance, a four-fold increase in transverse ductility of a 12 per cent. Cr steel disc. This may be accounted for by the occlusion of gases, particularly oxygen and hydrogen, which may be reduced by vacuum melting from 200 p.p.m. to approximately 4 p.p.m.

Appreciating the wider potential of this technique, Jessop-Saville Ltd. have invested about £500,000 in specialised plant for this purpose. Two types of furnace have been commissioned: (1) a Heraeus consumable arc furnace, capable of melting titanium ingots up to 24 in. dia. and 2½ tons in weight, and steel ingots up to 3 tons weight; and (2) a Wild Barfield N.R.C. high-frequency induction furnace, producing ingots up to 600 lb. They are the largest operating in the U.K. and are currently being used for steels, titanium and zirconium.

It is important to recognise that the advantages of vacuum melted steels must be considered for each particular alloy type and its application, for while the metal will be largely free of inclusions and residual elements, it will be more expensive and the mechanical properties are not always improved.

IN NEXT MONTH'S ISSUE

Principal features in the August issue of

ENGINEERING MATERIALS AND DESIGN will include:

Plastics Coatings
Corrosion protection by dipping and spraying.

Significance of Mechanical Properties of Metals in Design
Interrelation between proof stress/U.T.S. ratio, plasticity, fatigue and brittle fracture.

Principles of Hard Facing by Welding
Selection of alloys, wear and abrasion resistance and recent developments.

Selection of Gasket Materials
Survey of jointing materials for various purposes.

Materials for Peltier Cooling

THERE HAVE BEEN predictions recently that refrigeration and air conditioning may soon be accomplished on a large scale by electronic units without either the moving parts or chemical coolants used in present-day appliances. These predictions are based on the assumption that improved thermoelectric-cooling materials can be developed. Research to broaden science's knowledge of materials and techniques required for thermoelectric-cooling devices has just been started at the Battelle Memorial Institute in the U.S.A. Initially, the two-year programme is being sponsored by sixteen American industrial firms interested in research basic to the use of the so-called Peltier cooling effect for refrigeration.

The Peltier or thermoelectric-cooling effect is achieved when electric current causes heat to be absorbed at one junction of two dissimilar materials and released from another junction of the same materials. Devices utilising the Peltier effect require extremely pure materials having a closely controlled combination of electrical properties.

Dr. E. H. Lougher, who will co-ordinate the research at Battelle, has said: "The study will concentrate on the thermoelectric properties of materials which have thus far received relatively little attention for thermoelectric devices. Materials that have already been investigated extensively, such as bismuth telluride, are not included in the present study."

Synthetic Mica

SOVIET SCIENTISTS are reported to be giving close study to the problem of semi-industrial production of synthetic mica. Provided adequate technical resources are devoted to the project, they are confident that large crystals of the material can be produced in the next two or three years.

Most of the development work is on fluorophlogopite, a synthetic mica consisting of the same chemical element as natural mica, but with one of the chemical groups replaced by fluorine. Natural mica contains hydroxyl groups which, on heating the mica, begin to react with each other, with the result that water is eliminated at temperatures above 600-700 deg. C. When this occurs, the insulating qualities of natural mica are destroyed.

Fluorophlogopite retains its insulating properties up to temperatures of 1,300 deg. C. But while it is easily and quickly made in the laboratory, methods have not yet been found to produce crystals large enough for the production of condensers, gaskets and insulators. There are several plants in the U.S.A., for example, producing synthetic mica from small crystals. The principal difficulty is a purely scientific, crystallographic problem: certain laws governing the growth of large synthetic mica crystals are not yet sufficiently clear.

Fatigue of Engineering Structures

IT IS COMMON knowledge that a high proportion of engineering failures are caused by metal fatigue, and already many research organisations have devoted considerable effort to fatigue phenomena. The Council for Scientific and Industrial Research have now, following an approach from the Institution of Civil Engineers, set up a committee to review current research needs in the fatigue of metal structures. The committee will examine records of failures or accidents which might have been due to structural fatigue even if fatigue was not recognised as the initial cause. It will also review current research needs on fatigue by surveying existing facilities and will make recommendations to the Department of Scientific and Industrial Research concerning safety factors in design.

In view of the tremendous amount of work being carried out by many industrial firms and central research organisations in specialised fields, it would appear that one of the most helpful aspects of the work of the new committee will be the co-ordination of the country's efforts and the disclosure of factors which require greater attention.

FOR MORE INFORMATION

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Aerojet-General Corporation, Azusa, California, U.S.A.
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COURAGE NEEDED IN RESEARCH

THE nation's research effort must be increased and the application of its results intensified if industrial development is to proceed rapidly enough for this country to maintain its competitive position in world markets. This was the theme of the first annual report of the Research Council of the D.S.I.R. for 1956-7. The council, in its 1958 report just published, proposes a 70 per cent increase in expenditure for its second five-year plan, realising that world conditions are changing rapidly and that it must play its part in changing them. This is a bold step and one which deserves every possible support. However, it must be appreciated that in industry as a whole the percentage of turnover devoted to research is still less than that in many other countries. It is widely believed that for research to be really effective and useful it must be carried out by industry itself, and so the vital question is whether industry is following the Government's lead in devoting more time and money to research. There is much evidence to show that it is not.

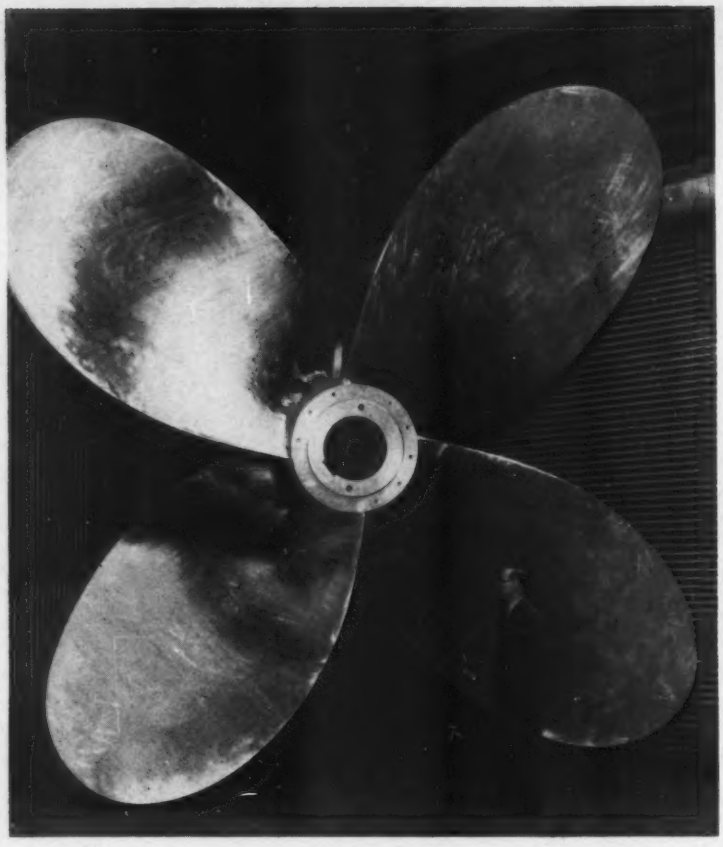
Research must always be expensive, although it is not —as many people have said—an expensive luxury, for when properly carried out it has great rewards. Such rewards are not necessarily confined to financial gain, for science and technology are now instruments of world politics, having tremendous influence on national prestige, self-confidence and self-respect. Soviet progress has aroused a world-wide public interest in scientific achievements, and it is a matter of national importance that we in this country should pay more attention to technical research and development.

It is therefore disturbing to find that some firms have recently made drastic cuts in their research expenditure and the outlook has not been improved by a recent prediction by Dr. Edward Teller, sometimes called the father of the hydrogen bomb, that Russia would be the unquestioned leader in science ten years from now. Our own Government, although setting a good example by allowing some tax reliefs on research expenditure and by increasing D.S.I.R. grants, has been subjected to some well-founded criticism in its space research programme recently announced by the Prime Minister. From the information so far available, the impression is given that the whole project is to be kept small and therefore cheap, but this hardly shows the spirit of enterprise and adventure which is the very essence of any worth-while research project. The mere voting of money does not, in itself, ensure that useful results will be forthcoming from a research programme, but there can be no doubt that lack of funds has frequently been a prime cause of failure. It is often difficult to persuade senior management to take the responsibility of voting money for research, but it is stimulating to hear the comments of Dr. N. A. de Bruyne, speaking at the recent opening of a new extension of CIBA (A.R.L.) Ltd. He said: "To summarise the most important conclusions we can draw from the past, . . . I would say that we have learned that there is no substitute for work that one enjoys and that when we have failed it was often because we were not courageous enough."

Here lies one of the greatest difficulties in our present society, in which more often than not the temptation to play for safety and security is irresistible. It takes great courage for a company director who is responsible to his shareholders or a Cabinet Minister who is responsible to his electors to propose the expenditure of large sums of money on projects which may not pay off for many years. On the contrary, the emphasis is usually on a quick return, so that priority is given to more straightforward decisions, such as the purchase of a new production machine, which can be shown with fair accuracy to pay its way in a few months. Unfortunately, balance sheets must be drawn up annually and net profit is too often the only objective.

Another factor which undoubtedly contributes to a conservative attitude in planning new designs and products is the committee system of control. In spite of frequent outbursts decrying their braking effect on progress, committees are becoming more numerous, and even if one or two members of a committee display courage in proposals for new lines of research, it is unusual to find a whole committee acting in this way.

The engineering designer is today faced with some formidable problems in providing such things as safe supersonic aircraft, efficient nuclear power stations and automatic factory units. Time frequently does not permit him to build up experience at each stage of development; he must therefore be prepared to make practical use of information gained from research and, if necessary, sponsor his own research in order to make progress at the rate demanded by foreign competition. This is not a matter of "keeping up with the Joneses" but is an essential factor in our economic survival. Research ideas must be translated into practical experiment several years ahead of their commercial exploitation and, especially in the application of new materials, designers must be courageous in their outlook because many of today's engineering problems can be met only by discarding traditional materials and methods and replacing them by new metals, plastics or ceramics which require unique treatment and a new design approach.



Face side of a 28-ton ship's propeller cast by the Manganese Bronze Co.

This article provides guidance in the selection of casting materials and discusses the advantages that they offer when used in various applications

by J. B. MCINTYRE, M.Sc., F.I.M.*

THE SELECTION OF MATERIALS FOR CASTINGS

CASTINGS have been made for over 5,000 years and in all branches of engineering they still play a vital part. The flexibility of casting production techniques enables practically all shapes to be produced, but the economic factor is an important feature in selection, together with the size and shape of the component, the metal or alloy indicated, the quantity and the dimensional accuracy required.

Articles of intricate design and modern engineering components in alloys of complex composition are usually cast. Ingots and shaped castings have many similar characteristics, though the subsequent application of each may be quite different. Both products are produced by pouring liquid metal or alloy into a shaped cavity called a mould, and each may vary from a few grammes to over 200 tons in weight. Similar problems are encountered in each case. They may be caused by either the thermal properties of the metal or alloy, the mould material used or by gas solubility effects and crystal growth. In all cases the size and shape of the metallic mass have a major effect upon the physical properties obtained in the casting.

Freedom from internal unsoundness in cast material is, in practice, a compromise between economy and the practical application of the product. The mechanical properties of cast material are directly influenced by the degree of soundness obtained, and freedom from porosity in any of the recognised forms is theoretically required if the maximum properties are to be obtained. Cast material is rarely produced in the absolutely sound state, though the properties required can always be obtained when correct techniques are used. Some variation in microstructure and macrostructure can be seen in alloys which have been cooled at a non-uniform rate. The cooling rate is very important and many ferrous and non-ferrous alloys are affected by variation in the cooling rate. It would appear that uniformity in microstructure and macrostructure is best obtained if the whole metallic mass under consideration is cooled at a consistent rate. This is difficult even when castings are of simple and uniform shape, but is practically impossible when shaped castings of non-symmetrical contour are considered. Sand castings are usually of the latter type. A mass of molten metal or alloy is cooled mainly by heat abstraction through the mould material and, as the latter becomes heated, heat transfer is decreased appreciably. Non-symmetrical castings may have many different section thicknesses which render the cooling problem even more complicated.

Foundry production techniques are based mainly upon methods designed to obtain the maximum degree of internal soundness, together with adequate surface finish and dimensional accuracy. In the sand casting process commonly used to produce shaped castings, intricate design is often combined with a slow and, in many cases, unpredictable cooling rate. It will readily be seen that shaped castings present considerable technical difficulties in addition to those normally encountered in ingot production, without the prospect of applying useful mechanical work to the product. Unsound ingots are by no means unknown, but unsoundness often disappears after working.

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Casting Methods

The main casting production methods are die casting and sand casting. The former includes all methods which use a static metal mould, while sand casting, as its name implies, involves the use of sand moulds. Considerable overlap exists in practice, as metal moulds may have sand inserts and sand moulds are frequently made with metallic inserts. Theoretically, any casting may be produced by either method, but practical limitations are imposed by casting size and design and, equally important, by the material required. Large castings are generally produced in sand moulds, since metal dies quickly become unwieldy if the casting weight exceeds a few pounds. In the main, metal moulds are limited in application because of the high cost which is incurred if the casting design is complicated or the alloy pouring temperature is high.

Sand moulds tend to be somewhat wasteful, since all of the technique used in their production is wasted when the mould concerned is broken to remove the solid casting. The sand casting process is still the most flexible of all methods used for the production of shaped castings. Much of the skill required for the successful production of sand casting lies in the techniques used to avoid mould erosion and to compensate for the liquid shrinkage occurring as the casting cools to the solidus temperature. Casting design is an important factor when arrangements are made for the running and feeding of castings.

The mould filling capacity of metals and alloys is of obvious importance in castings production. Considerable differences can be observed in the "fluidity" (or mould filling capacity, as it is preferably known) of various alloys. Most pure metals and alloys of eutectic composition have excellent mould filling capacity; grey cast iron is notably good. In the light alloy field the aluminium-silicon material made to L.M.6 (B.S. 1490) is outstanding for the production of intricate designs or thin sections, and phosphor bronze of the type P.B.I.C. (B.S. 1400) also has a high mould filling capacity. It is not possible to generalise in this matter, for so many factors are known to influence mould filling capacity. These include chemical composition, pouring temperature, type of mould material, and casting design; in addition, there are a host of smaller yet inter-related factors which cannot be ignored. It may be expected from casual observation that the alloys which need a high pouring temperature have a poorer mould filling capacity than those normally poured in the lower temperature ranges.

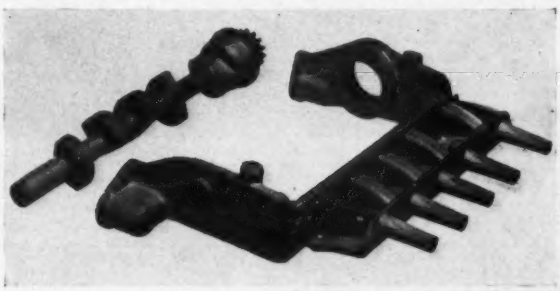
In many cases casting design is the doubtful factor, and it may be economically wiser to consider dividing the proposed design into smaller units more amenable to economic production. The smaller castings could then be assembled by welding or some other arrangement. The alloys of foundry interest are not all weldable to the same degree. Steels are notably good in this respect and cast irons are not so suitable. Most of the bronzes have useful welding capacity and, since the development of argon-arc and similar methods, the light alloys present few problems. The casting assembly shown at the foot of this page is an example of the additional flexibility conferred upon the casting process by welding. In many cases, particularly in chemical plant construction, castings are welded to fabricated assemblies.

Casting Designs

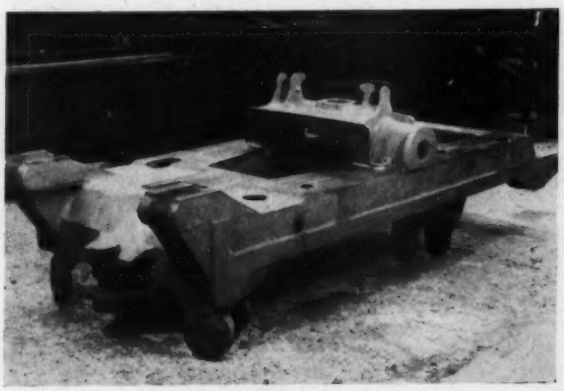
These are obviously dependent upon the application of the components, but must inevitably be influenced also by the properties of the material used. The best designs are therefore those which are compatible with the intended use of the castings, taking into consideration both the average physical properties required and the foundry characteristics. The solidification characteristics of each foundry alloy differ and it is not possible to make generalisations. Certain principles are established, however, which enable sound castings to be produced regularly and which are capable of satisfying all requirements. There is great need for the designer to co-operate with the founder, preferably where the knowledge already gained in the foundry can be of service. Many castings are difficult to produce as originally designed, and the founder's knowledge and previous experience can often enable him to suggest modifications to the original design which facilitate production without loss of efficiency in service.

The maximum information should be available on the drawing of the proposed casting. Close tolerances should be clearly indicated and the location points for machining made clear. It is important to state the nature of the machining operations, and automatic machining methods particularly require material having completely reproducible properties where hardness, machinability and freedom from defects are concerned. It is general practice now for large consumers of castings to submit casting designs for consideration before plans are made for production, and this co-operation could usefully be developed even for small orders. Not all castings are machined, however, but may be required in such large quantities that the weight of each must be closely controlled if economic production is to be maintained. This important factor is dependent upon the selection of the best production method. Despite general belief, apparently complicated designs are not necessarily the most difficult to make in a sound state. Even simple shapes can cause difficulty if an unsuitable alloy is used. It is likely that the familiar marine propeller is one of the few designs which approach ideal, in that it is symmetrical, with the section changes blended smoothly into one another, and the massive boss located in a central position well placed for feeding.

In all cases when a modification is considered, the



Gravity die cast automobile castings in aluminium bronze by the Aluminium Bronze Co.



How casting and welding can be combined to advantage: a bridge welded to a separately cast steel frame.

following points are worthy of attention:

1. Will the modification reduce production costs?
2. Will foundry or machine shop scrap be reduced?
3. Will the application or appearance of the casting be impaired?

When these points can be answered to the satisfaction of all directly concerned, then the prospect of wholly efficient castings production becomes real.

Various casting production methods are available, each having characteristics of interest to designers. Sand moulds are still standard for castings in most alloys, whether the number of castings needed is small or large. Intricacy of design is no handicap; nor is casting size. Machining allowances on sand castings made by jobbing methods tend to be substantial in comparison to those provided on castings produced in other ways. Dimensional accuracy is dependent upon the pattern equipment provided, but tens of thousands of sand castings are made daily by mechanised methods, each dimensionally accurate within the limits specified. Such accuracy is maintained by the provision of suitable equipment at each stage in production.

When quantities of castings are required to close dimensional tolerances, then shell moulding methods should be considered. This technique is applicable to practically all alloys of engineering interest and is more popular for castings of relatively small size. Remarkable castings are made in ceramic moulds by Shaw methods or investment moulding. Very fine detail and close dimensional accuracy are outstanding characteristics of those methods. Any type of alloy can be handled, although the production costs are naturally greater than those in sand moulding. The scope of investment moulding is well known, but the Shaw techniques may be less familiar. Small castings, or those weighing up to 40 or 50 lb., can be readily handled by Shaw methods. Accuracy is rather less than that obtained by investment, but Shaw castings find increasing application for the many purposes where a considerable amount of machining would otherwise be needed. For example, see top of page 361.

Small castings in large numbers are normally made as die castings, provided the alloy is suitable. Gravity die casting is available for aluminium, magnesium alloys, for the brasses and aluminium bronzes. Pressure die casting methods are limited to the light alloys and to zinc base alloys. Pressure die castings can be made in very large numbers and generally to closer limits than sand castings or gravity die castings. Good surface finish is another useful feature of gravity and pressure die castings.

Grey cast iron no doubt owed its original use to the ease with which it could be melted and cast, and to the need for an economical alloy for domestic and engineering applications. These characteristics remain attractive to designers, and cast irons continue to find extensive use for a variety of applications. The rigidity and high damping capacity of grey irons are special features of great value in many components ranging from pianoforte frames to machine tool castings. A high resistance to frictional wear is demonstrated in a host of ordinary engineering applications and good high-temperature resistance and rigidity are obvious requisites in the grey iron moulds which are standard throughout the world for steel ingot production. Certain types of grey iron, some of the older magnesium alloys and certain copper base materials show section sensitivity. The remedy is clearly to select the grades of each alloy known to be least sensitive and to arrange casting designs so that great variation in section thicknesses are avoided. Due attention must be paid to iron composition when castings of varied section thickness are required, but this matter can usually be left to the technical staff of the foundry concerned. Castings production in the higher grades of cast iron may involve special techniques and is more expensive than that required for the lower grades of this material. Casting sections under $\frac{1}{4}$ in. thick are more readily made in the lower grades of cast iron which are listed in the standard specification. In all cases consultation between founder and customer is advantageous.

Ordinary grey irons are not ductile and are unsuitable for those applications where moderate physical properties, including a measure of ductility, are required.

In such cases malleable iron should be considered. Two

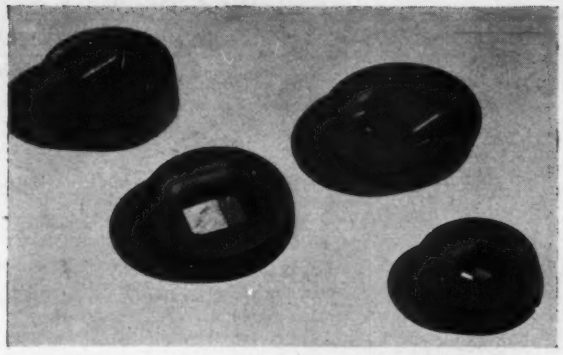
TABLE 1. Properties and characteristics of aluminium casting alloys

B.S. 1490	Casting Characteristics			General Properties			Uses and General Remarks
	Sand casting	Gravity die	Pressure die	Corrosion resistance	Machinability	Capacity anodising	
L.M.1	F	G	F	P	G	U	General-purpose gravity die castings.
L.M.2	G	G	G	G	F	G	General-purpose alloy especially suitable for pressure die castings.
L.M.3	G	U	U	P	G	F	General-purpose sand casting alloy.
L.M.4	G	G	G	G	G	G	General-purpose alloy with good foundry and mechanical properties.
L.M.5	F	F	F	E	G		For use where corrosion resistance is of first importance, e.g., marine applications.
L.M.6	E	E	G	E	F	G	Large intricate and thin castings. High corrosion resistance.
L.M.7	G	G	F	G	G		General-purpose alloy.
L.M.8	G	G	G	E	F	E	Good corrosion resistance, e.g., marine work.
L.M.9	E	E	G	E	F		As L.M. 6 with higher strength and lower ductility.
L.M.10	F	G	F	E	G		High strength and shock resistance.
L.M.11	F	F	U	F	G		Good physical properties.
L.M.12	F	G	U	P	G	U	Medium-duty pistons.
L.M.13	G	G	F	G	F		Most piston and cylinder heads.
L.M.14	F	G	U	F	G	G	High duty pistons and cylinder heads.
L.M.15	F	G	U	G	G		Similar to L.M.14.
L.M.16	G	G	G	G	G		Intricate designs when high strength needed.
L.M.17	G	G	G	G	F		As L.M. 6, but better at elevated temperatures.
L.M.18	G	G	G	E	F	G	High corrosion resistance, good casting alloy.
L.M.19	F	F	U	F	E		Free machining alloy.
L.M.20	E	E	G	G	F	G	As L.M. 6, better machinability.
L.M.21	G	G	F	F	G	G	General-purpose casting.
L.M.24	F	G	E	G	G	U	Good pressure-tightness.

Symbols: E—Excellent; F—Fair; U—Unsuitable; G—Good; P—Poor.

types are available, Whiteheart and Blackheart, the former being particularly suitable for light sectional work and the latter for applications where fairly high yield stress and elongation are required. The so-called spheroidal graphite irons are relatively new and have found application for many purposes where good mould filling capacity, high-strength shock resistance and ductility are required. The shock resistance is good and these irons are the subject of B.S. 2789. Ductile irons, as they are sometimes known, are competitive in some respects with steel castings, but are not quite so easily welded. There is no doubt that they will become much more popular in future with designers.

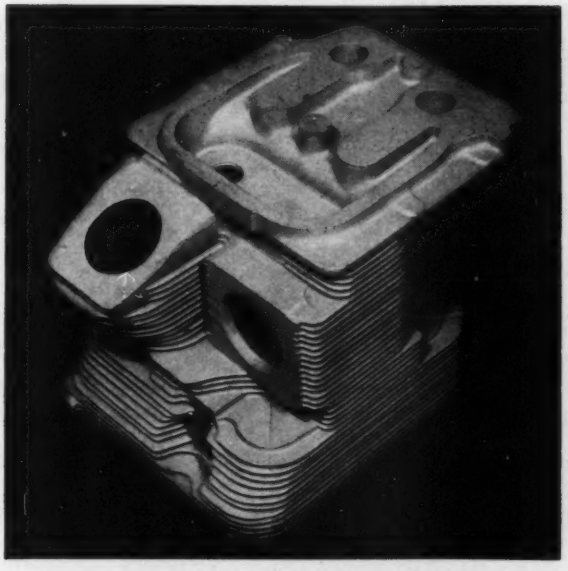
Various alloy cast irons have been available for many years; they are suitable for wear-resisting or certain types of corrosion-resisting work, depending upon the composition of the iron concerned.



Extrusion die inserts cast by the Shaw method by Samuel Osborn Ltd. If produced from solid stock, they would normally require much machining.

Pure Metals

Few pure metals are produced in sand cast or die cast form, since the poor physical properties obtained from such materials are not attractive to designers. In addition, most pure metals are more expensive, and tend to be more prone to gas absorption than are their alloys. In modern practice it is sometimes desirable to make castings in material of high electrical or thermal conductivity. Such castings are used for certain components in chemical processing plant and dairy equipment. Aluminium or copper castings designed for water cooling are widely used for electrode conservation in electric arc furnaces and for tuyeres and cooling plates in iron blast furnace operation. Copper is considerably more popular than aluminium for the purposes mentioned and the latter metal is used only on a limited scale. Substantial quantities of copper castings are employed by the electrical industry in which the high electrical conductivity of pure copper is of great value. A limited amount of commercially pure aluminium is used in the production of domestic hollow-ware where the high corrosion resistance of this metal is another advantage.



Pressure die cast light alloy cylinder head with 3-4 per cent vanadium steel inserts. The die required 164 moving parts. A product of Sterling Metals Ltd.

Steel

British Standards dealing with steel castings are grouped under B.S. 3100:1957, which embraces many types of steel commonly used for castings. Some proprietary grades are also made, but much of the industrial requirements can be met from the alloys included in the grouped specifications. Carbon steels represent a very substantial part of all steel castings made.

Plain carbon steels serve an extremely wide range of engineering purposes, but when unusual combinations of physical properties or other special features are required, such as resistance to abrasion, heat, creep or corrosion, then the use of alloy steels is indicated.

Aluminium Alloys

The aluminium alloys of engineering interest are substantially covered by B.S. 1490. (See Table 1.) L.M.6 is an old alloy which continues to be popular, especially for castings required to be pressure-tight or highly corrosion resistant. The comparatively new alloy, L.M.4, has gained a well-deserved reputation as a reliable general-purpose material, and is now of considerable importance. Many of the standard aluminium alloys are improved by appropriate heat treatment, but this should not be carried out if the as-cast cheaper materials will serve. If specific physical property, such as high proof stress, is required then a heat-treated alloy is indicated. Cost may be an important factor and in such cases alloys such as L.M.2 may be preferred to the more expensive L.M.6 variety, especially where good machinability is required. As in all other alloys, the design required is extremely important. Despite

Zinc pressure die casting for a carburettor.

TABLE 2. Specifications and common applications of casting materials

Material	Appropriate British Standard	Characteristics and Applications
Grey cast iron	1452 Grey iron castings	Seven grades numbered according to tensile strength. Easily melted and cast, economical, high damping capacity and some resistance to friction. Low impact strength and not ductile. Domestic uses, machine tools, automobiles, ingot moulds, and general engineering.
Malleable iron	309 Whiteheart malleable iron castings	Two grades. Ductile, can be worked by twisting and bending; can be galvanised. Used mainly for light sectional work. Castings up to 50 lb.
	310 Blackheart malleable iron castings	Three grades. High yield stress and elongation. Used for automobiles, some pipe fittings, tractors and mining equipment.
S.G. cast iron	2789 From castings with spherical or nodular graphite	Grade 1 (pearlitic) can be heat treated. Grade 2A (ferritic) for general work and grade 2B for good machinability. Good mould filling capacity, high strength and ductibility, good shock resistance. Not so easily welded as steel.
Alloy irons		High wear and corrosion resistance depending on composition. E.g., 12–14% silicon alloy: for chemical plant in contact with H_2SO_4. Ni-Resist: austenitic, non-magnetic, wear-resistant. Used for electrical equipment, chemical plant.
Steel	3100 Steel castings for general engineering purposes	Ductile and weldable
	592* Carbon steel castings for general engineering purposes	Used for marine, chemical, mining, civil, heavy transport.
	1504 Steels for use in the chemical petroleum and allied industries	Weldable. Used for pressure tight vessels in petroleum and chemical industry.
	1617* Mild steel castings of high magnetic permeability	Electrical applications.
	1760* Carbon steel castings for surface hardening	Engineering work where some abrasion is found, but toughness is also needed.
	1456* 1½% manganese steel castings	High yield stress and ductility. Used for ordnance applications and general engineering.
	1458* 45/55 ton alloy steel castings 1459* 55/65 ton alloy steel castings	Good abrasion resistance. For structural, crushing and rolling purposes.
	1398* Carbon-molybdenum steel castings	Creep resistant up to 450 deg. C. Used for high temperatures and pressures such as turbine and power station equipment.
	1956* 1% chromium steel castings	Excellent physical properties; abrasion resistant.
	1457* Austenitic manganese steel castings	Good wear resistance at room temperatures; useful for crushing and grinding equipment.
	1630* 13% chromium steel castings	Outstanding corrosion resistance; not easily machined; limited temperature resistance.
	1631* Austenitic chromium-nickel steel castings	Good corrosion resistance. Grade A unsuitable for welding, grade B containing columbium or titanium can be welded. Good corrosion resistance. Creep resistant to 400 deg. C. Physical properties less than B.S. 1630.
	1632* Austenitic chromium-nickel-molybdenum steel castings	Outstanding corrosion resistance. Used for certain highly corrosive fluids.
	1648* Heat-resisting alloy steel castings	Good heat resistance (remains rigid and free from scaling).
	1461* 3% chromium-molybdenum steel castings	Corrosion resistant to 400 deg. C. High ductility in thick sections.
	1462* 5% chromium-molybdenum steel castings	More corrosion resistant than 1461 at high temperatures, more resistant to hydrogen enbrittlement. Used for oil refineries.
	1463* 9% chromium-molybdenum steel castings	Better corrosion resistance to B.S. 1462.
Aluminium alloys	1490 Aluminium and aluminium alloy ingots and castings	See Table 1.
Magnesium alloys	1272-80 Magnesium alloy ingots and castings	Two-thirds the weight of aluminium. Good machinability and castability; readily die-cast to high accuracy and good finish. Used for aircraft, automobile, textile machinery, portable tools, typewriters, etc.
Copper alloys	1400 Copper alloy ingots and castings	1. Phosphor bronze: PB1 for chill cast; PB2 for gear blanks; PB3 (more ductile) for chemical plant. 2. Leaded phosphor bronze: LPB1 used for bearings. 3. Aluminium bronze: AB1 non-magnetic, corrosion- and abrasion-resistant. AB2 similar to AB1, but with higher tensile strength. Greater scope in corrosion resistance. 4. Brass: B1. Resistant to atmospheric corrosion and free machining. B2. Cheaper than B1. B3. For good surface finish. B4. High purity, high elongation. For gravity die casting. B5. Naval brass. Similar to B4, but modified for marine corrosion resistance. B6. A best-quality, low zinc, can be brazed.
Nickel alloys	1537 Nickel-copper alloy castings	Corrosion and high temperature resistance. Chemical plant, dairy equipment, steam valve trim.
Zinc alloys	1004 High purity zinc, zinc alloys: for die casting and zinc alloy die castings	Excellent surface finish. For castings up to 20 lb. Low costs. Good mould filling capacity. Not recommended for temperatures above 100 deg. C. Cannot be easily soldered or welded. Usually given a painted or plated finish. For automobiles, decorative or domestic uses.

* Included in B.S. 3100

the supreme flexibility of the casting process, some designs are either impossible to make as castings or can only be made satisfactorily in one alloy from a given range. The apparently wide range of alloys which constitute B.S. 1490 has been chosen to enable the often conflicting requirements of design, cost and application to be reconciled. In recent years, the economics of the pressure die casting process has led to a substantial increase in the use of this technique, but not all of the alloys included in B.S. 1490 are suitable for pressure die castings. All light-alloy founders are willing to advise in the matter of alloy selection for specific purposes.

Magnesium Alloys

Magnesium alloys are the lightest structural alloys available, magnesium metal being only two-thirds the weight of aluminium. Such alloys are obviously of interest for aircraft components, but also can be valuable in many other engineering applications where a high strength-to-weight ratio is important and good machinability and castability are of value.

These alloys are readily die cast, and gravity die cast components are used to advantage in many powered portable drills, saws and grinders. Pressure die castings in magnesium alloys are remarkable for their dimensional accuracy and excellent surface finish. The somewhat expensive dies have an extended life when magnesium alloys are cast; this may be important if large quantities of castings are needed. The commercial grade, electron "C", can be supplied either in the "as-cast" state or after heat treatment; the physical properties are adequate for many purposes.

Copper Alloys

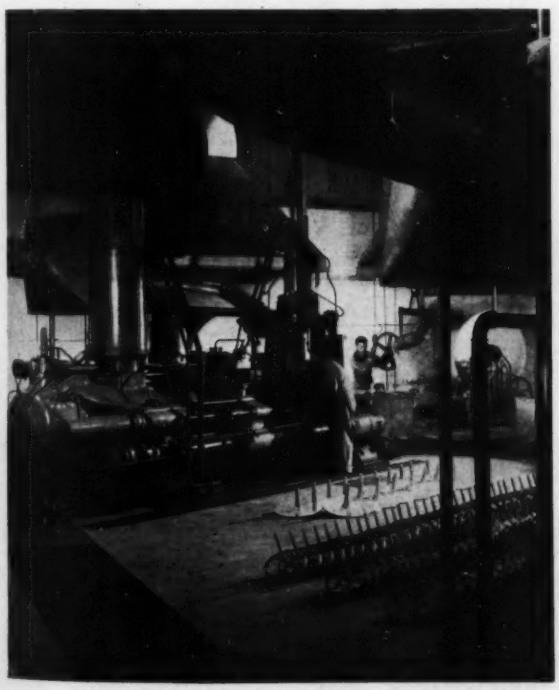
Copper base alloys find their application where useful corrosion resistance and wear resistance are regarded as essential. In recent years the leaded gunmetals in series L.G. have become competitive, since they are cheaper, no less easy to cast and have properties adequate for many purposes. For pressure-tight requirements they can sometimes be preferable to the straight gunmetals. The more stringent requirements of high loading in service, conditions are difficult and loading is particularly high, then the lead bronzes are used. They are three in number, varying in lead content; the higher lead alloys tend to be more difficult to handle by ordinary foundry techniques.

The engineering work which involves greater stresses, coupled with somewhat better resistance to mild corrosion conditions, are met by the phosphor bronzes.

Bearings in gunmetal, whether leaded or not, are frequently lined with lead base or tin base whitemetal. When higher resistance to corrosion and abrasion, will exclude the tin bronzes, but the aluminium bronzes serve remarkably well in such cases.

Silicon bronzes generally compete, when sand cast, with the tin bronze groups, mainly the gunmetals. Silicon bronzes have been somewhat neglected by designers, though they have been available for many years. They are often preferred for low-temperature applications. The brasses are not used to any extent where good physical properties are essential, since the gunmetals are regarded as superior; they serve for many purposes where resistance to mild corrosion is needed and where their excellent mould filling capacity is an advantage.

The high-tensile brasses are those alloys formerly known as manganese bronzes. They combine good resistance to marine corrosion with substantial physical properties and have a high mould filling capacity.



This aluminium alloy pressure die casting machine at High Duty Alloys Ltd. is one of the largest in the U.K.

Nickel Base Alloys

The wide range of nickel alloys available for castings have been formulated to deal with corrosion conditions of all kinds and in some cases for service at high temperatures. Monel-type alloys are basically nickel copper materials devised for corrosion resistance in dairy and chemical plant; the Hastelloy group is intended for acid handling and manufacture. Several grades of each are available for specific purposes and the foundry concerned will always be able to help in the selection of an appropriate grade. The best heat-resistant group of alloys known at the present time is the Nimonic series, which are primarily nickel-chromium alloys containing other elements for specific applications. The casting grades of Nimonic are readily handled by investment methods; alloy selection for given purposes is no problem, since investment founders are always available for consultation.

Zinc Base Alloys

Zinc base alloys are widely used for pressure die castings. The extremely good mould filling capacity of both alloys "A" and "B" in this specification has caused them to be specified for very many applications in light engineering and various domestic applications. Their physical properties are adequate, though the alloys are not generally recommended for applications above 100 deg. C.; they cannot readily be soldered or welded. Some of the smallest castings made are in zinc base alloys, but pressure die castings up to 20 lb. have been made. Some form of coating is usually applied to castings in these alloys, such as painting or plating; the excellent surface finish which is always obtained on such castings facilitates the application of chromium plating for decorative purposes.

The specifications and characteristic applications given in Table 2 should be regarded as broad coverage only. There are very few applications which can be regarded as limited to one type of alloy; the economic factor may prove to be the most important, based upon maintenance cost or the actual cost of the casting. *Actual* costs should not ignore the potential scrap value of the casting when adequate service has been obtained.

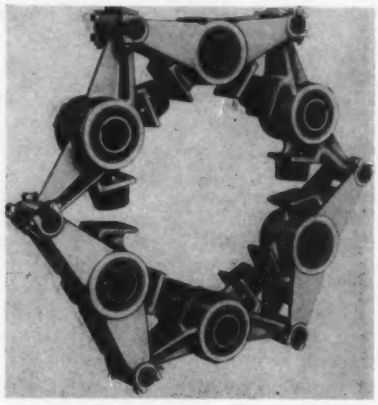
NEW IDEAS IN DESIGN

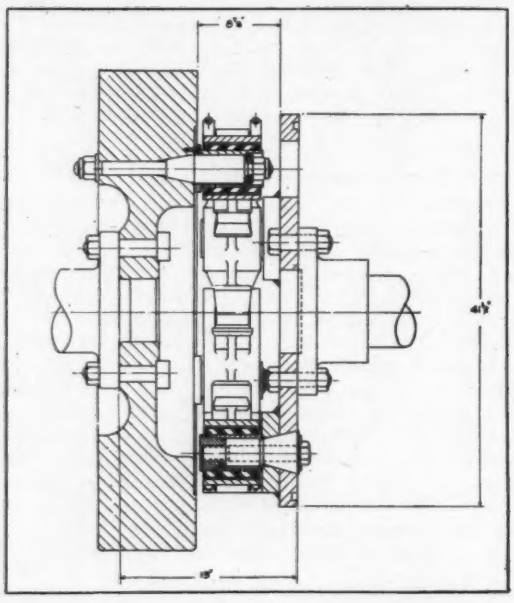
Outstanding products in current manufacture

Torque Transfer Coupling Uses Rubber in Shear

THE torque transfer coupling illustrated is claimed by the manufacturers, Metalastik Ltd., to be an effective and economical solution to the problem of resonant torsional vibration in the marine engine/propeller-shaft system.

Initially a very low stiffness is provided, with a much higher value for a predetermined torque. The ratio of initial to final stiffness can be varied as required. It will be seen that although initial torque is transmitted by the rubber in shear (in the bonded rubber bushings), for higher torques the rubber buffers come into operation and provide the greater stiffness required.





The coupling illustrated is 45 in. in diameter and 7½ in. wide. It is fitted between the flywheel and gearbox of a marine diesel engine developing 1,000 b.h.p. at 435 r.p.m. At 6,000 lb./ft. torque, the torsional deflection is 7¼ deg. The design is stated by the manufacturers to be suitable for drives of 500-1,000 b.h.p. at 435 r.p.m., or equivalent torques up to 500 r.p.m.

Three rocker arms are connected at their extremities by special shackle pins. Each arm pivots centrally on a heavy-duty rubber-in-shear bush. Bonded rubber buffers are bolted to flats formed on three of the rocker arms. One set of rockers is connected by three tapered pins to the flywheel and the other set by three pins to the gearbox flange. The inner sleeves of the centre pivot bushes are keyed to the pins in each case.

At present being fitted to new Ruston & Hornsby marine diesel engines, the coupling conforms with Lloyd's requirements.

Crankshaft Eliminated in High-pressure Waste-Pump

THE Hydraflo, a high-pressure pump developed by Tangye Ltd. for coal infusion work (but by no means restricted to such duty), represents a considerable departure from the traditional in the design of reciprocating pumps.

In place of the conventional system of gears, crankshafts and connecting rods normally used to reciprocate the pump plunger, hydraulic means are employed. A number of considerable advantages are claimed by the makers to have resulted from this design. Heavy bearing pressures and high torques associated with crank-driven pumps are eliminated, and also a smaller and more compact unit is possible. The kind of items which may eventually have to be replaced are small and inexpensive. On the performance side, a large diameter piston working at a slow speed is used, which provides an almost straight-line continuous output.

The accompanying diagram illustrates the working principle. A 1,450-r.p.m. induction motor is direct coupled through a flexible coupling to a high-speed oil pump. Oil is drawn from the tank through a suction strainer and delivered to a sequence valve which controls the flow of oil to the driving cylinder. The oil piston assembly reciprocates and, as it is integral with the water cylinder, pumping is achieved. Reversal of the stroke is brought about by a mechanically-operated trip mechanism which operates the sequence valve. The trip mechanism ensures self-starting under all conditions and its action is controlled by dampers which gives a smooth, quiet change-over. As the dampers are continuously fed with oil they need no attention. The trip mechanism is operated by tappets, actuated by sleeves, mounted in the banjo attached to the end of the oil piston rod and reciprocating with it.

Compactness of the reciprocating unit is achieved by positioning the water cylinder unit inside the oil cylinder, with provision for the positive separation of the oil from the water.

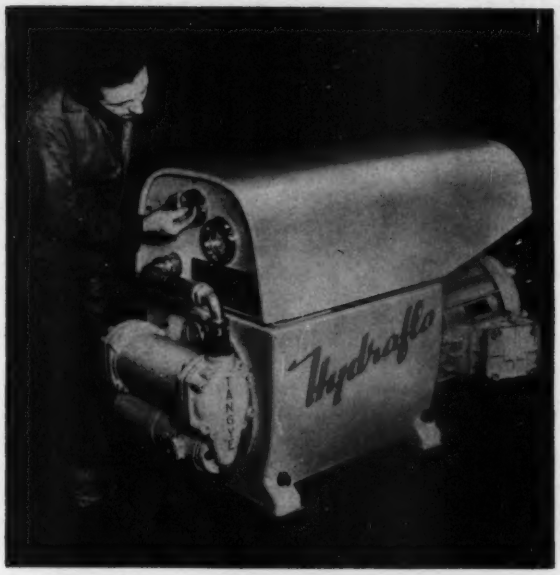
Overload protection is provided by an automatic

pressure unloader valve which permits oil to flow freely back into the tank from the oil pump, with little resistance. It is brought into operation when loading exceeds a marginal allowance over normal duty and so prevents the pump from continuously blowing through a relief valve when overloaded. It is designed to allow the pump to idle, taking little power, and to restart the pump automatically when the pressure is reduced. Should the pump be left unloaded for long periods, a thermal unit reduces any heat generation to a safe level and guards against possible over-heating due to abnormal conditions.

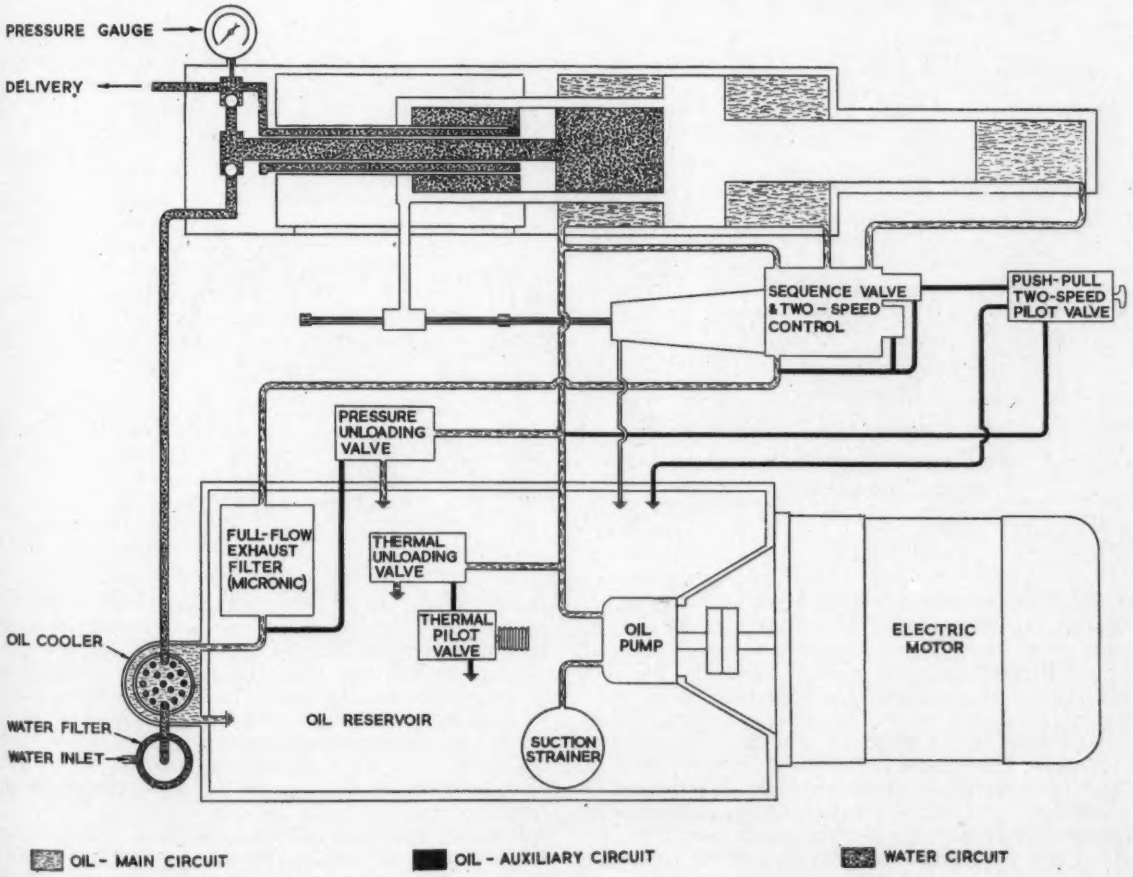
All dynamic seals are of the automatic metallic type and are claimed to require no attention during their working life. Rubbing surfaces are of hard chrome-plating or close-grained wear-resistant material. Working parts exposed to water are non-corrosive.

The water valve box is of high-tensile S.G. iron and is fitted with loose, renewable, high-tensile bronze valve seats and valve lift, allowing restricted flow and quiet operation. The valve assembly is fixed by a single bolt and is easily withdrawn as a complete unit.

The extreme compactness of the unit is partly achieved by making the reservoir for the hydraulic oil also contain the oil pump, suction strainer, full-flow pressure-type micronic filter, unloader valves, thermal unloader and thermostat. One end of the tank is blanked off by a cover which carries the oil cooler, water filter and oil-level indicator. The reservoir also serves to carry on its exterior the electric motor. It will be seen that adequate lubrication of all working parts is ensured by this arrangement.



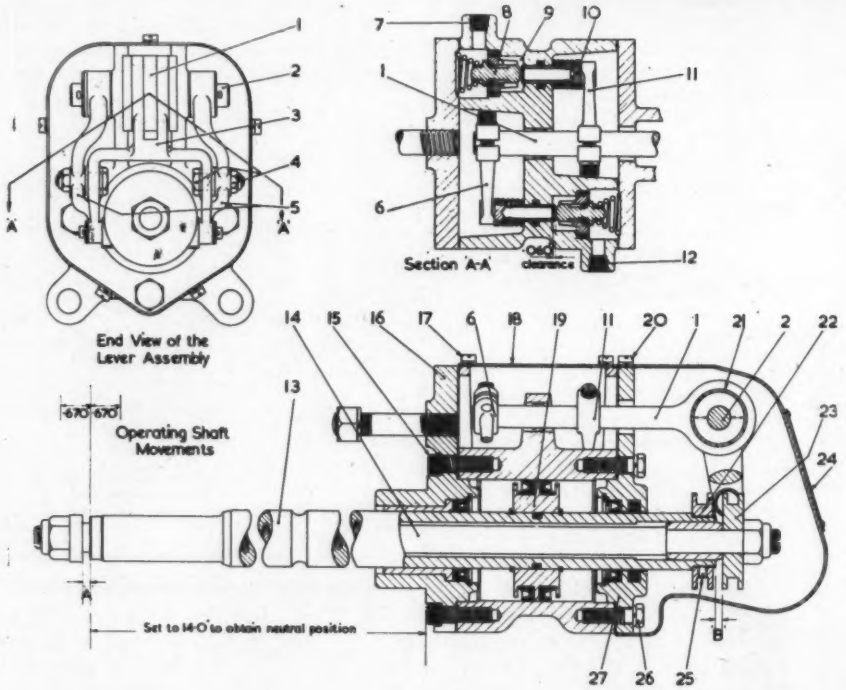
The Hydraflo pump is capable of outputs of 1,000 gallons per hour at 1,500 p.s.i. or 500 gal./hr. at 3,000 p.s.i. For future development pressures up to 6,000 p.s.i. are envisaged, with outputs up to 3,600 gal./hr.



Vehicle Gearbox Servo Utilises Compressed Air

COMPRESSED air from the vehicle braking system is utilised in the new Clayton Dewandre gearbox servo. It is designed for attachment to the gearbox, with the actuating and operating shafts passing through the gearbox housing. The inner actuating shaft is coupled to the gear lever and the gearbox toggle arm is clamped to the outer operating shaft. Movement of the gear lever reciprocates the actuating shaft within the operating shaft, opening either of the two distributor valves and permitting air pressure to be supplied to the appropriate side of the double-acting piston, to augment the driver's effort. Should the air pressure fail, the gearbox can still be operated manually with increased effort.

The servo (see illustration below) consists of a lever assembly, through which movement is transmitted to the rod operating the distributor valves, the operating shaft which forms the piston rod, together with the inner actuating shaft and the distributor valves.



The initial rearward movement of the gear lever reduces the clearance at A, moving the actuating shaft (14) to the right within the operating shaft (13), increasing the clearance at B between the two collars (22) and (23). The lower ends of the reaction lever (3) are carried to the right, pivoting on the pins (4) in a scissor action, moving the distributor valve rod (1) to the left. The valve operating lever (11) moves forward the spring-loaded valve plunger (10), which seats against the distributor valve (8), cutting off the connection to atmosphere, and further movement opens the distributor valve (8), allowing air pressure from port (7) to pass into chamber (9) and through the passages in the body into the left-hand side of the cylinder. As the air pressure rises in the cylinder it moves the piston (19) and operating shaft (13) to the right, assisting the gear change so long as the driver continues the effort on the gear change lever. When the gear has been engaged the operating shaft will override the actuating shaft, which is retained by the gear lever, decreasing the clearance B between the collars. This causes the reaction lever to pivot so that the top is again centrally disposed over the shaft (2) and the valve rod (1) moves to the right, allowing the distributor valve (8) to seat and the atmospheric valve to open, releasing all air pressure in the cylinder to atmosphere.

Forward movement of the gear lever increases the clearance at A and reduces the clearance at B, moving the distributor valve rod (1) to the right. This causes the opposite distributor valve to be operated, admitting air to the right-hand side of the cylinder.

STEPLESS TRANSMISSION GEAR WITH CONSTANT MESH

An ingenious mechanism for providing an infinitely variable transmission ratio with a constant mesh formed the subject of a paper by G. A. Blokh, published recently in the Soviet journal, Priborostroenie. *Working principles of the gear are explained here by stages*

THE variety of stepless transmission techniques available to the designer today is almost endless. Because of the very nature of their action, however, none of the existing friction transmissions guarantees an accurate and stable transmission ratio.

The infinitely variable gear transmission being considered in this paper is free from the short-comings of a friction transmission, as it provides for infinitely variable changes in the speed of the driven shaft yet transmits rotation through positive geared meshing.

As can be seen in Fig. 1, the set of gears consists of a flat disc (1), the face of which has rectilinear teeth forming a rack, and an ordinary pinion (2) of the same pitch as the rack.

The pinion (Fig. 2) is set in two ball bearings and runs free on spindle (1) fixed in a ring which, in turn, is pressed into the inner race (2) of a ball bearing. The outer race (3) of this ball bearing sits in a housing (4), which, by sliding along the guides (5), carries the pinion towards the centre of the disc or away from it. When the pinion is engaged with the disc (Fig. 1) and fixed spatially by the housing (4) (Fig. 2) being clamped tight, then, with the disc being rotated at a constant angular speed ω, the pinion will have two motions:

1. a relative one round the spindle (1) at a variable angular speed $\omega_0 = f(\alpha)$;

2. a displacing one, i.e., together with spindle (1) round the ball bearing axis $O - O'$ at a constant angular speed ω_n.

Let the disc be rotated through angle α (Fig. 3).

When $\alpha = 0$, i.e., before the disc rotates, pinion tooth cd engages the horizontal disc tooth CD. With the disc rotating through angle α, the pinion turns in relative motion through angle β and in displacing motion through angle α. In order to find the relation $\beta = f(\alpha)$, we draw an arc of radius ρ from the disc centre O.

Tangent EF at angle α on this arc represents the disc tooth which meshes with a tooth of the pinion after the latter's rotation through angle β. The length of arc subtending angle β along the pitch circle of the pinion will be

$$S = \rho - \rho \cos \alpha = \rho (1 - \cos \alpha) \qquad (1)$$

therefore

$$\beta = \frac{S}{r} = \frac{\rho}{r} (1 - \cos \alpha) \qquad (2)$$

where r is the pitch circle radius of the pinion.

With $\alpha = \omega t$, the circular speed of the pinion in relative motion will be

$$v_0 = \frac{dS}{dt} = \frac{d\,[\rho(1 - \cos \omega t)]}{dt} = \rho\, \omega \sin \omega t \qquad (3)$$

the angular speed of the pinion in relative motion will be

$$\omega_0 = \frac{v_0}{r} = \frac{\rho}{r} \sin \alpha \qquad (4)$$

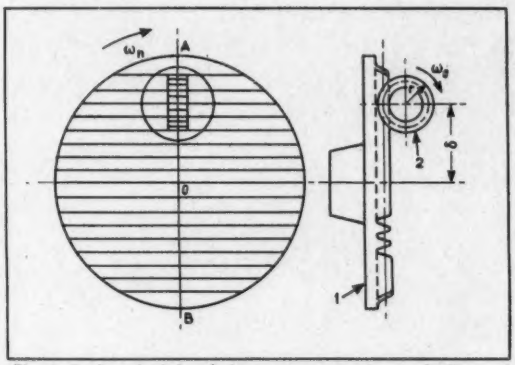


Fig. 1. Basic principle of the gear—a rotating rack disc and a pinion.

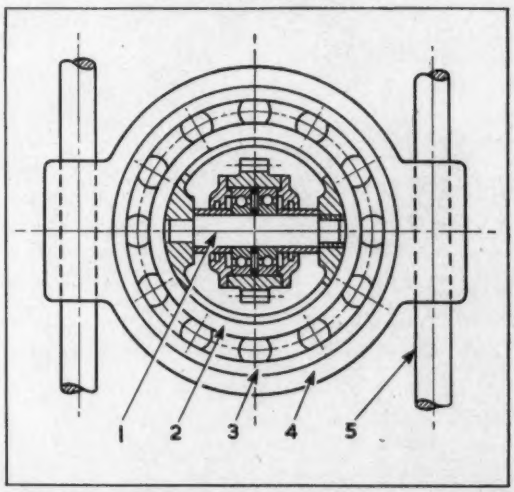


Fig. 2. Pinion mounted inside the inner race of a ball bearing.

and the angular acceleration

$$j = \frac{d\omega}{dt} = \frac{\rho}{r} \omega^2 \cos^2 \alpha \qquad (5)$$

There is also the sliding motion of the pinion tooth along the disc tooth. The path of this sliding is

$$s = \rho \sin \alpha \qquad (6)$$

and the sliding rate

$$v_t = \frac{d\,(\rho \sin \omega t)}{dt} = \rho\, \omega \cos \omega t \qquad (7)$$

Formula (4) shows that the angular speed of the pinion in relative motion is proportional to ρ and changes in accordance with the sine rule. Since the sine changes its

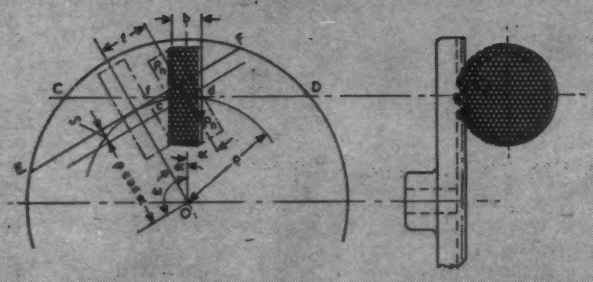


Fig. 3. Relative angular displacement of pinion with rotation of rack disc.

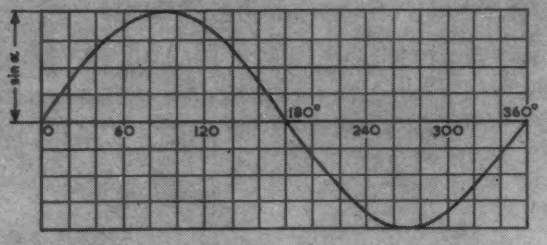


Fig. 4. Sinusoidal output with pinion reversal obtained with one disc rack only.

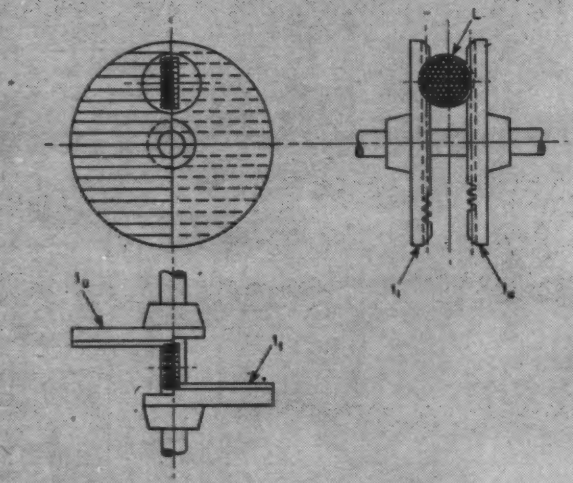


Fig. 5. Two half discs, above and below pinion, giving continuous rotation.

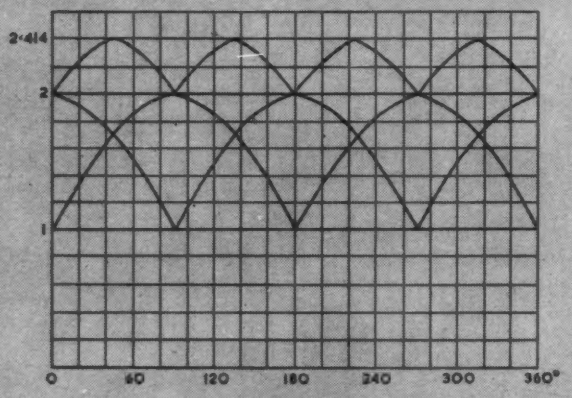


Fig. 6. Output obtained with two pinions and two disc racks as in Fig. 7.

sign after each 180 deg., the pinion will change the direction of its rotation after each half turn of the disc, and this change will take place along the diameter AB (Fig. 1). The angular speed of the pinion in displacing motion is equal to the angular speed of the disc.

Thus, when the disc has rotated through 360 deg., the pinion will be back in its original position, having made one turn in displacing motion. The gear ratio i_a of this pair for complete revolutions is 1, the value for ρ being immaterial.

It is a kinematic pair of the third class and can be used in special instruments, for instance in co-ordinators requiring an angular speed which changes according to the sine or cosine rule; in this case, two pinions, placed 90 deg. apart on the disc, will be required, one of them providing the sine-rule change of the angular speed, the other the cosine-rule change.

For cases where the rotation of the pinion is to be reversed and/or uniform rotation in one direction to be obtained during one complete turn of the disc, let the latter be cut in half along diameter AB (Fig. 1), i.e., a lower half l_l and an upper half l_u (see Fig. 5). Let the two halves be separated by a distance equal to 2r, inverted so that their toothed sides face each other, and let the original centres be joined by a shaft.

On turning the half-discs, the pinion will no longer change the direction of its rotation, since during the first part of its turn (from 0-180 deg.) it will mesh with the lower disc-half l_l, and during the second part (180-360 deg.) with the upper half l_u. It must be noted that during the transition of the pinion from one disc-half to the other its relative angular speed $\omega_0 = 0$. The transition will consequently be smooth, especially since the pinion has an even number of teeth with slightly bevelled tips.

The Reducer

The reducer consists of two disc-halves (Fig. 7), arranged and mounted as described above on a shaft (1) which turns on bearings in the casing (2).

Pinion (3) is housed in a rotating case and is permanently fixed to bevel gear (4). Through bevel gear (5) and spur wheel (6) it transmits rotation to the case (7), which has inner and outer gearing.

The axis of gears (3 and 4), and the spindle bearings of gears (5 and 6) are located in a ring (8) which runs in two ball bearings (9). The outer race of (9) is fixed into the inner surface of the case (7). The latter is held in a collar (10) which has a toothed section on its outside.

Two pinions (3), rotating in two separate cases (7), are employed for the purpose of equalising the angular speed of the reducer. The collars of their cases are located 90 deg. apart round the centre of the disc.

The cases (7) have gearing on the outside (on top of the upper case, along the bottom of the other) by means of which they mesh—through the idler (11)—with two spur wheels (12). The latter have integral bevel gearing (13) and, together with planet gear (14), form a bevel differential.

The outside ends of the cross-member of the differential has a bevel gear (15) which rotates shaft (16).

The collars (10) pivot round the axes of the idler gears (11). These axes are fixed in two rigid plates (17) which are permanently attached to the casing (2).

The toothed section of the left-hand (horizontal) collar engages gear wheel (18), the spindle of which has a hand wheel fixed on its end. The two collars are joined by a stay (20). When the hand wheel (19) is turned, the cases with the pinions (3) are brought nearer to the disc centre or moved away from it; this alters the gear ratio of the reducer. The change in the speed should be carried out during running. The reducer is reversible, i.e., the drive shaft can be the driven shaft and vice versa. The drawing shows the driving and driven shafts as being located at

right angles to each other; however, if required, a coaxial reducer can be constructed by joining the two disc halves l_1 and l_{II} by an exterior transmission and fixing the cross-member of the differential rigidly to the drive shaft which will have the same axis as the driven shaft. Gears 15-16 will in this case not be required.

Taking into account the nature of the differential, the gear ratio of this reducer in transmitting motion from the disc to the wheel can be expressed by the equation

$$i_p = i_2 \frac{\rho}{2ri_1} \left\{ \left[(\sin \alpha) \frac{\pi}{0}^{\frac{\pi}{2}} + (\cos \alpha) \frac{\pi}{0}^{\frac{\pi}{2}} \right] + 1 \right\} \quad (8)$$

where i_1 is the gear ratio of the gears inside the cases, i.e., $i_1 = i_{4-5}\ i_{6-7}$;

i_2 is the gear ratio of the remaining gears, i.e., $i_2 = i_{15-16}\ i_{12-7}$.

The above formula (8) shows that this gear ratio, and, consequently, the angular speed of the driven shaft, depends upon α.

Fig. 6 shows the fluctuations in the angular speed of the driven shaft. The curves are based on the magnitudes inside the braces of formula (8).

The degree of non-uniformity in this case will be

$$\varepsilon = \frac{2{\cdot}414 - 2}{2{\cdot}207} = 0{\cdot}1875$$

In order to achieve optimum rotation regularity for the working element of a machine, the delivery shaft of the reducer could be coupled to the driven shaft by an elastic drive, e.g., a spring coupling or a spiral spring. In addition to this, a flywheel could be fixed behind the spring on the driven shaft of the working element.

The coupling and the flywheel together will act as accumulator and compensator as the spring will come under tension at i_{max} and slacken at i_{min}. Its elasticity, together wtih the flywheel momentum, will even out the irregularity of the rotation of the driven shaft.

The efficiency of such a reducer in transmitting motion from the disc to the pinion can be expressed in the following equation:

$$\eta_{i_n} = \frac{(1 + i_1)\ (\sin \alpha + \cos \alpha)}{(1 + i_1 + f)\ (\sin \alpha + \cos \alpha) + \frac{2f}{b} i_1 \rho}\ \eta_{\varkappa} \quad (9)$$

where f is the friction coefficient of the sliding of the pinion tooth along the disc tooth; b the width of a pinion tooth; $\eta\varkappa$ the efficiency of the gear wheels (apart from wheels 1-2).

An analysis of formula (9) shows that the efficiency of the reducer depends on ρ, i and α. It also depends on the width (b) of the pinion tooth, because in the displacing motion of the pinion (2) in Fig. 1 a twisting moment is applied to the tooth at the expense of the couple applied at the tip of the pinion tooth (Fig. 3):

$$M_n = P_n b$$

The magnitude of this couple determines the friction force of the sliding along the tooth; the greater, therefore, the width (b), the smaller the sliding friction force and, consequently, the greater the efficiency.

There are two cases in which the gear transmission discussed here can find practical use:

1. In co-ordinators for the purpose of reproducing sin α and cos α functions in the place of the present link mechanism of the Wolf type, or the SVT rotary transformer.

2. As an infinitely variable reducer in the place of the friction variator. This reducer can be recommended obviously only for instruments and low-power drives in view of the fact that transmission inside the reducer occurs at a variable angular speed and also because efficiency is comparatively low due to losses through friction in the sliding of the pinion teeth along the disc teeth.

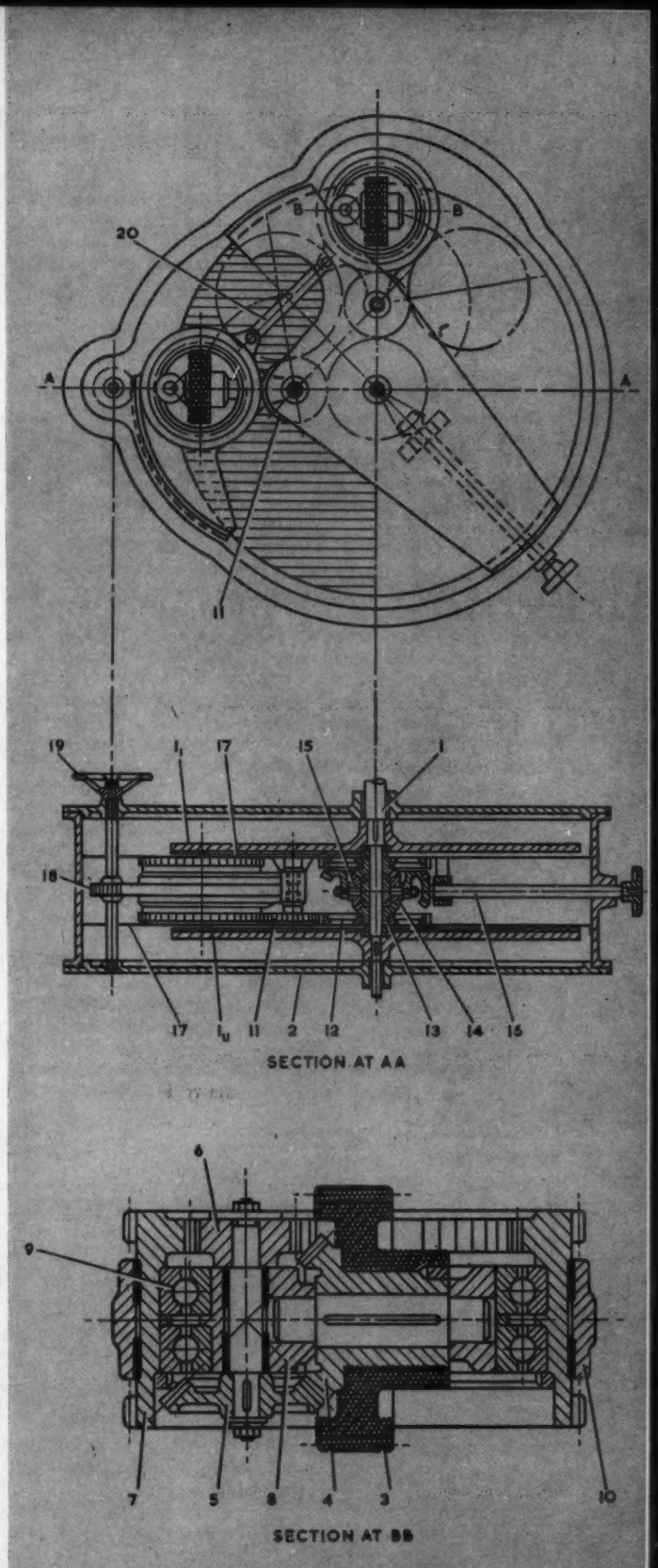


Fig. 7. A possible embodiment of the invention using a bevel differential gear to connect the outputs from each of the two main pinions (shown in colour). Section BB illustrates the manner in which drive from a main pinion is taken via a bevel gear to an internal gear cut in a spool. On the outside of the spool are gear teeth which transmit drive via idler gear (11) to the spur wheels (12).

PLASTICS AT HIGH TEMPERATURES

THE problem of selecting materials for skins of hypersonic vehicles operating in gas temperatures ranging from 5,000-7,000 deg. K. is one about which scientists are somewhat pessimistic, since the materials selected must have some degree of stability at such temperatures for the vehicle to survive until the completion of its mission. One possible solution involves the use of organic plastics which, although not stable above 300 or 400 deg. C., may fail slowly enough to be useful.

Two important facts emerge from studies of this problem. One is that the optimum material for one mission may be quite inferior for another. The second is that it would appear that mere chemical considerations can be quite as crucial as the mechanical and other physical properties. Among the variables, particular attention should be drawn to the enthalpy or heat content of the gas determining heat flow from the gas to the material.

Fig. 1 shows the values of enthalpy plotted as a function of temperature for argon, carbon dioxide and water. Thus the erosion of a material in argon at a particularly high temperature may be quite a bit lower than that of the same material in water or carbon dioxide at the same temperature.

When the erosion of a selected group of plastics is observed in the different gaseous environments generated in the facilities mentioned above, it is found that the relative performance in the group changes very markedly with the temperature, as shown in Fig. 2.

It should be noted that the material which is relatively least durable at 2,000 deg. C. is relatively most durable at 7,000 deg. C. Furthermore, the influence of resin content is quite different at the three test temperatures. Higher resin content leads to lower relative erosion rates at the higher temperatures and higher relative erosion rates at the low temperature.

The theoretical heat-absorbing capacity data given in Table 1 provide a rational basis for considering organic materials for parts exposed to very hot gases, since among structural materials the reinforced organics have the higher potential heat-absorbing and gas-generating capacity. Some attempt has been made to take the melting process into account in the data shown in Table 2.

TABLE 1. Estimated integrated specific heats from 300-5,000 deg. K. and equilibrium volume of gas generated per gram at 5,000 deg. K. for various substances

SUBSTANCE	HEAT ABSORBED (cal./gm.)	RELATIVE GAS VOLUME (mol.)
Hydrogen	67,000	1·0
Organic plastics $(CH_2)_n$	24,000	0·21
Organic plastics $(CH)_n$	20,600	0·15
Graphite	16,670	0·08
Water	14,500	0·16
Beryllium	9,876	0·11
Beryllia	7,080	0·08
P.T.F.E.	6,300	0·06
Cellulose	5,760	0·10
Magnesia	5,500	0·05
Helium	3,525	0·25
Silica	2,800	0·05
Copper	1,600	0·016

TABLE 2. Liquefaction and vaporisation temperatures and estimated efficiencies of various substances

SUBSTANCE	MELT °C.	BOIL °C.	EFF. (%)
Hydrogen	−260	−253	0
Graphite	—	4,200	99
Water	0	100	0
Beryllium	1,278	2,970	6
Beryllia	2,530	3,900	26
Magnesia	2,800	3,350	24
Helium	−272	−269	0
Silica	1,710	2,300	22
Copper	1,083	2,336	6

The rating of carbon in both tables is noteworthy. As would be expected, under severe conditions of exposure this is perhaps the most erosion-resistant material known. However, its structural properties up to 1,500 deg. C. and thermal conductivity complicate some of the design problems which occur in missiles.

** Condensed version of a paper presented at the recent S.A.E. National Aeronautical Meeting in the U.S.A. by Irving J. Gruntfest, G.E.C. aerosciences laboratory.*

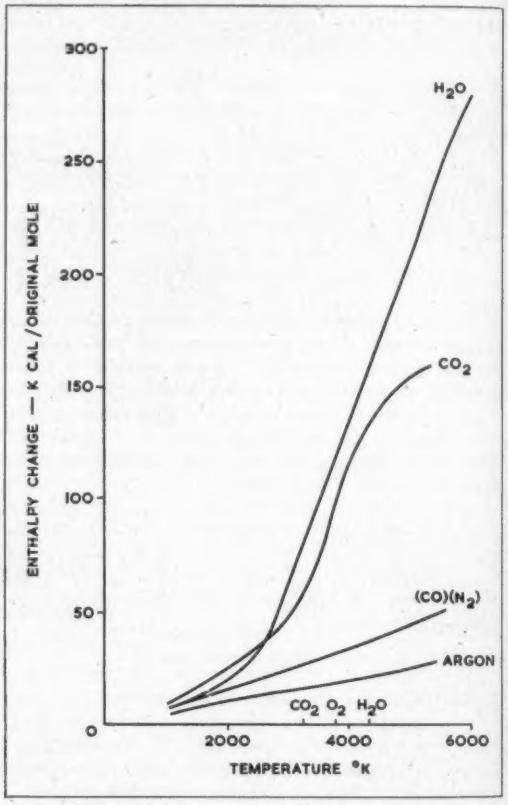


Fig. 1. Enthalpy as a function of temperature for various gases (approx.).

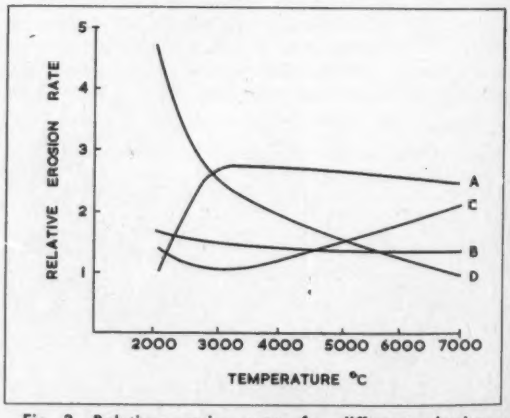


Fig. 2. Relative erosion rates for different plastics as a function of temperature. A—glass phenolic 27 per cent resin. B—glass phenolic 65 per cent resin. C—refrasil phenolic 41 per cent resin. D—nylon phenolic.

NEW TRENDS IN USING AIR SUSPENSION

This article provides the designer with an examination of the principles and practice of air suspension, and of the methods of application in which it can offer the greatest advantages

by K. E. NICHOLDS, A.M.I.Mech.E.*

THIS year has seen the public showing of a variety of air suspension systems on British vehicles. The system has already been employed in Europe and in the U.S.A. to the extent that G.M. coaches and the majority of American cars now have it as an optional fitting.

Although it has so far been accepted for use on a number of road vehicles, the future possibilities presented by air suspension have yet to be fully explored. It is worth examining here first the fundamental reasons for providing a vehicle with a suspension system and the particular advantages that air suspension may offer in certain applications.

So long as roads have irregular surfaces, however slight the irregularity may be, movement over them by a wheel results in vertical movement of the axle. Traces recorded electronically show that even on apparently smooth, level roads the relative movement between axle and chassis is appreciable. This relative movement gives rise to accelerations which impose loads on the chassis and contents, and, being variable accelerations, give rise to shock loading, which is unpleasant to driver and passengers and damaging to vehicles and freight. The size of the shocks may be diminished by properly springing the chassis upon the axle.

* *Design engineer, Hymatic Engineering Co. Ltd.*

The analysis of the motion of a chassis is complicated by the facts that the forcing function, i.e., the road surface is indefinable, and that the human definition of unpleasant or pleasant riding is subjective, although curves are available showing average opinions on the frequency-amplitude relationship of an acceptable ride. Also, the vehicle wheels are coupled to the chassis in a necessary but complicated manner, and complicated modes of vibration arise in practice. The problem has, however, been studied in this country at the National Physical Laboratory at Teddington, at Cornell Aeronautical Laboratory in the U.S.A., and elsewhere. In Germany, the Short Bros. analogue computer has been used to simulate the response of a chassis to road conditions.

The treatment in this article is simplified. The spring rate of the tyre is assumed constant, the variation in the damping coefficient of the shock absorber is neglected, and the exciting force is supposed to arise from a wheel riding over a sinusoidal surface. The sprung mass connected to the wheel will move in space sinusoidally, but with different phase to the exciting vibration. The designer is concerned to keep the shocks imposed on the load down to an acceptable value. Thus, if the wheel is executing a motion $X = X_o \sin \omega t$ due to the road surface, the chassis will execute a motion $x = x_o \sin (\omega t + \alpha)$, and the shock will be given

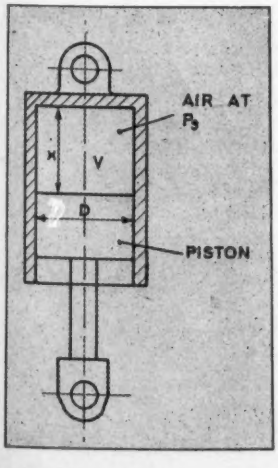


Fig. 1. Left. Basic principle of the simple air spring.

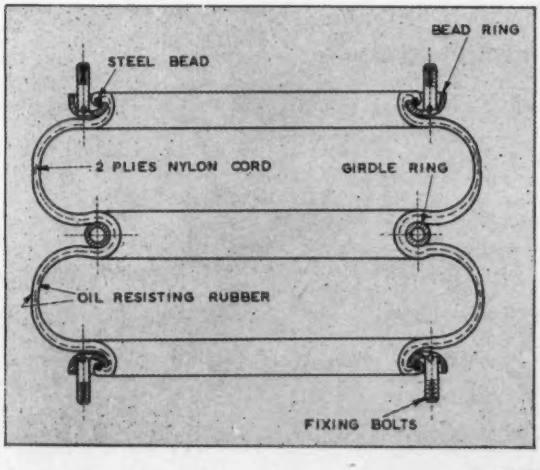


Fig. 2. Right. Double-convolution air spring.

by d^2x/dt^2 or $-\omega^2 x_o \cos(\omega t + \alpha)$, and the shock impressed by d^2X/dt^2 or $-\omega^2 X_o \cos \omega t$. The proportion of the shock felt is x_o/X_o, the transmissibility factor for the suspension.

For a simple spring, this is given by $\frac{1}{1-(\omega/\omega_n)^2}$ where $\omega/2\pi$ is the frequency of the forced vibration, and $\frac{\omega_n}{2\pi}$ is the "natural" frequency of the spring-mass system.

As can be seen from Fig. 3, the low-frequency vibrations tend to be transmitted in full, and the proportion transmitted is amplified as their frequency increases towards the natural frequency of the system; the high frequency vibrations tend to be reduced or attenuated. It follows that:

1. A damper or shock absorber is necessary to limit transmissibility at the natural frequency (i.e., at resonance).
2. The lower the natural frequency, the lower the transmissibility of normal shocks, the value of which depends on (frequency)^2 as well as amplitude.

It may be thought that the sinusoidal analysis is too far divorced from reality for it to be applicable. This is not really so, because a sine wave is not a bad approximation to an undulating road, and an isolated pot-hole or bump can be regarded (by Fourier Analysis) as generating a wide band of sine-wave displacements of the wheel and chassis.

The natural frequency of a sprung mass is given by $\omega_n = \sqrt{\frac{c}{m}}$, where c is the stiffness of the spring and m is the mass in slugs. Since the natural frequency of the system varies with the weight supported, the transmission of shocks is greater for a lightly laden vehicle than a heavily laden vehicle, supposing the spring rate to be constant. An accentuating factor is that accelerations due to riding a bump increase as the square of the forward speed. With a constant rate suspension a higher road speed would have to be maintained to give the same attenuation of bumps with a light load as with a heavy load, but the higher speed increases the magnitude of the shock.

For constant ride quality irrespective of load, constant natural frequency is required, and variable damping.

Thus the stiffness/load ratio should be constant.

This is satisfied ideally by a spring where the stiffness varies exponentially with deflection, as shown in Fig. 4. It will be noticed that the rate does not permit much load variation for 6-in. deflection.

The exponential stiffness characteristic, or the rising rate characteristic, as it is called, is difficult to achieve exactly in practice, but it will be appreciated that any spring which approaches the ideal gives a better ride over the range of loading than a constant rate spring.

Rising Rate Springs

As will be shown later, air springs have inherently the characteristic required. They are not the only springs having this property.

Leaf-springs may be given the required characteristic by correct proportioning and stepping or may, by the linkage employed, have the desired characteristic for vertical deflections.

Coil springs may in theory be made rising rate by allowing them to become progressively coil bound, but this is not very practical and a linkage device is better.

Torsion springs require a linkage to give the desired property.

Rubber springs have inherently the desired property.

Liquid springs have a rising rate characteristic, since the compressibility or bulk modulus of a liquid is a function of pressure.

The Air Spring

For the purposes of first analysis the air spring may be considered as shown in Fig. 1. If the load carried increases, the pressure rises and the volume decreases, generally as a polytropic relationship:

The rate or stiffness C, i.e., dW/dx is given by

$$\frac{dW}{dx} = -n\,\frac{A(W/A + 14{\cdot}7)}{x} \text{ or } -n\,\frac{A^2(P_g + 14{\cdot}7)}{v} \text{ lb./in.}$$

The natural frequency is given by $\omega_n = \sqrt{c/M}$, or

$$\omega_n = \sqrt{\frac{n\,Ag}{W.x}\,(W/A + 14{\cdot}7) \times 144} = \sqrt{\frac{K}{v}\,(1+14{\cdot}7\ A/W)}$$

where W = load; x = deflection; n = compression index; A = area of spring; P_g = air pressure (gauge); v = volume.

Thus as the sprung mass increases, the natural frequency approaches a constant value. Fig. 5 shows the relationship for a typical air spring, compared with a coil spring giving the same natural frequency laden.

While a low natural frequency and a rising rate characteristic can be provided by methods other than air springing, the resultant rate is so low that there is a large variation in chassis standing height between laden and unladen conditions. It is desirable to keep the c.g. of the vehicle low to give good road holding, while the lowest chassis height is governed by the clearance necessary to clear kerbs, hump-bridges, etc. The chassis standing height when air springs are used can be readily varied by varying the weight of air within the spring. Referring to the last equation it will be seen that if the standing height is constant, the volume is constant, and for oscillations of not too large amplitude the natural frequency remains fairly constant.

Fig. 7 shows the relationship between standing height and load, and Fig. 6 between transmissibility and frequency, for a coil and an air sprung vehicle, laden and unladen. The diagram is computed for a 3:1 variation in laden weight; this is low for a commercial vehicle but high for a car. It will be seen that, although the peak transmissibility alters, the natural frequency of the air sprung vehicle is substantially constant, while that of the constant rate suspension increases as the load is removed. For greater variation in laden/unladen weight, the variation is more marked.

Types of Air Spring—There are four basic types of air spring:

1. The piston and cylinder arrangement which was used for discussion of air spring characteristics. This suffers from difficulties in sealing the unlubricated sliding parts, and is not used in practice.

2. The Citröen hydraulic jack in which the oil pressure is communicated via a membrane to a sealed gas-filled vessel, compression of which by displaced oil provides the required resilience. While this system gives control of standing height by regulation of the quantity of oil in the jack, the fact that the gas volume varies means that constant frequency cannot be attained over a wide range of loads.

3. The double convolution bellows. This is illustrated in Figs. 2 and 12, showing a cylindrical unit and an elongated unit respectively. The walls are constructed of nylon-reinforced rubber. The spring is bolted to a sealing plate top and bottom, and an air connection made through the top plate. The elongated unit is similar in principle but has the advantage that it fits the space left by the normal leaf spring. Both these springs are normally too bulky for a car installation but find their place in trailer and commercial vehicle construction.

4. The fourth type is called the rolling lobe air spring, illustrated in Fig. 13. Here there is a nylon-reinforced diaphragm sealing the surge tank to a central pillar, or

FIG.3.

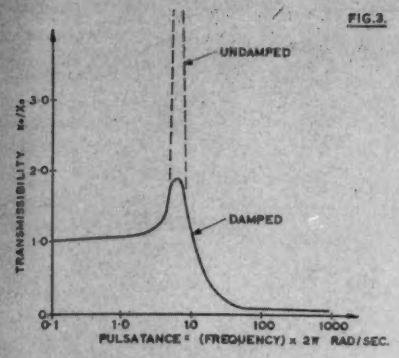


FIG.4

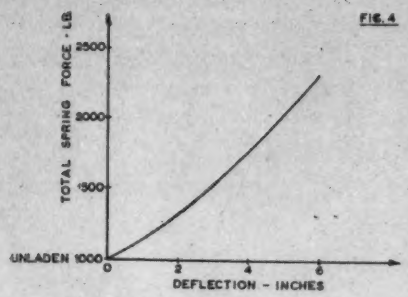


FIG.5.

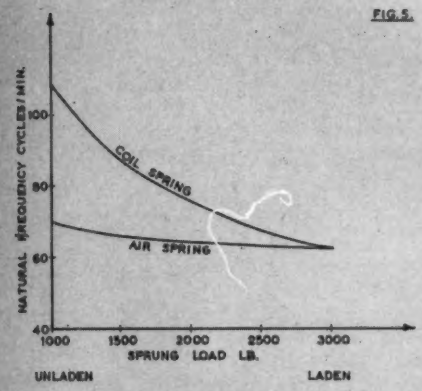


FIG.6.

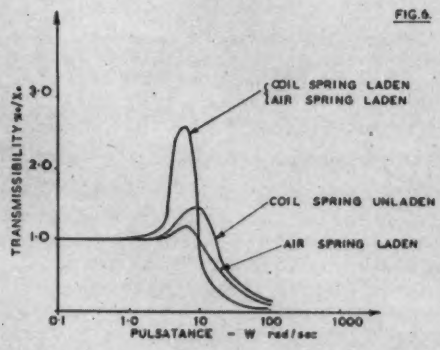


FIG.7.

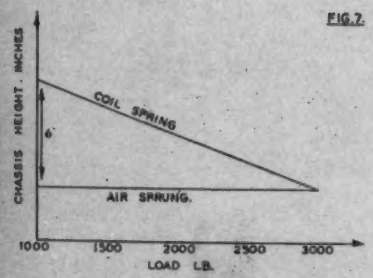


FIG.8

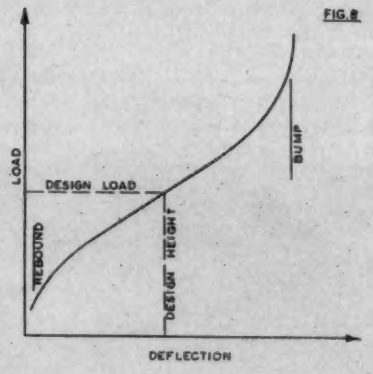


FIG.9.

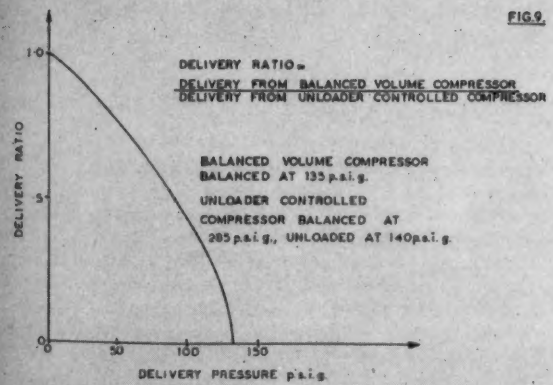


Fig. 3. Transmissibility-frequency curve for 1,000 lb. sprung weight, 1,670 lb./ft. spring rate and 137 lb./ft./sec. damper rate.

Fig. 4. Constant frequency spring load-deflection relationship.

Fig. 5. Variation of natural frequency with sprung weight. Both springs give same frequency laden.

Fig. 6. Variation of transmissibility with load.

Fig. 7. Variation of chassis height.

Fig. 8. Rolling lobe air spring characteristic.

Fig. 9. Comparison between balanced volume and unloaded compressor.

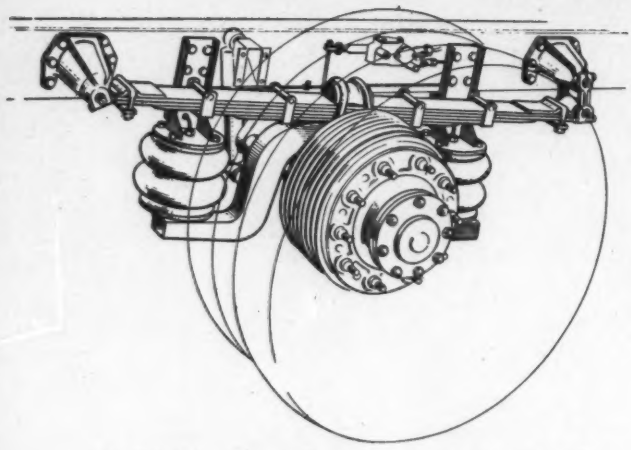


Fig. 10. This air suspension system developed in the U.K. by Leyland Motors Ltd. has been supplied to the Netherlands Railways for experimental use.

pedestal. The effective diameter D_e, used in the relation $W = \frac{\pi}{4} D_e^2 . P_g$ is the diameter equal to the length of the tangent to the lobes. This can be altered as the stroke varies by altering the shape of the pedestal. A pedestal profile must be found so that the correct rate is given at each part of the stroke. General Motors are said to have designed the 1958 Pontiac pedestal profile using an I.B.M. computer.

It is desirable, over and above the rising rate inherent in an air spring to have, first, increased rate towards the bump stop and, second, the rate should rise rapidly towards the rebound stop. The first feature provides against "crashing through" to the bump stop after hitting a pot-hole, while the second reduces the duty of the rebound stop. The characteristic is shown in Fig. 8.

INSTALLATION OF AIR SPRINGS—The air spring has no lateral or fore-and-aft stability so that axle location by Panhard rods, etc., is necessary. It is recommended that the suspension should be designed for air springs, rather than adapted.

Manufacturers state that the minimum natural frequency for double convolution air springs is in the order of 80-85 cycles/minute. This is high by current trends but the frequency may be lowered, either by fitting a surge tank or by installing the air spring on a trailing arm, as shown in Fig. 14.

If S_1 is the spring rate, $S_1 = dR_1/dx_1$

Since $x = x_1 b/a$, $R = R_1 a/b$; $R/x = R_1/x_1 . (a/b)^2$

Then $S = (a/b)^2 dR_1/dx_1 = (a/b)^2 S_1$

Thus the natural frequency becomes $f_n = 2\pi\sqrt{\frac{gs}{w}}$

$= 2\pi \frac{a}{b}\sqrt{\frac{g.s_1}{w}}$ where (a/b) may be varied.

PROVISION OF AIR SUPPLY—Regulation of height means that air will be used, and a supply will have to be provided. A quick calculation shows that the capacity of a reasonable-sized storage bottle is not sufficient to allow of more than a few changes in load before it would be empty. An air compressor is therefore required: this is best made an engine-driven accessory, either direct drive or belt driven. The size and delivery pressure of the compressor are decided by these factors:

1. How big an air reservoir can be fitted.
2. How quickly air needs to be provided to charge the system.
3. How high a pressure is used in the air springs.
4. How the standing height of the chassis is controlled.
5. Whether air is exhausted to atmosphere or to a low-pressure reservoir.
6. How often load changes occur.

Of these, 3, 4 and 5 are interrelated parts of the control system. 1 and 2 can be decided as follows:

(a) The minimum size of air reservoir needs to contain enough air to charge the air springs of a vehicle when it is first loaded, assuming air is present at low pressure in the air springs before loading. Thus for a vehicle of 3,000 lb. sprung weight laden, and 1,500 lb. sprung weight unladen, if directly sprung on an 80 p.s.i. maximum air spring pressure system, 0·035 lb. of air will be required. If the reservoir pressure is not to drop below, say, 90 p.s.i., and the maximum pressure in the reservoir is, say, 110 p.s.i., the volume required to ensure that a 20 p.s.i. drop in pressure results in at least 0·035 lb. flow of air is $\frac{1}{4}$ cu. ft.

(b) If the maximum acceptable pump-up time at $\frac{1}{4}$ engine speed (say 1,000 r.p.m.) is one minute, and the combined capacity of reservoir and air springs is $\frac{1}{4}$ cu. ft., and the compressor runs at an average volumetric efficiency of 50 per cent. the compressor must be large enough to deliver $2\frac{1}{2}$ to 3 c.f.m. free air delivery pumping against 90 p.s.i. It is therefore important, in order to keep the compressor size small, to make the system as leak-tight as possible.

Factor 6 is usually the least important, except for a city bus, where the air make-up time between stops may be small.

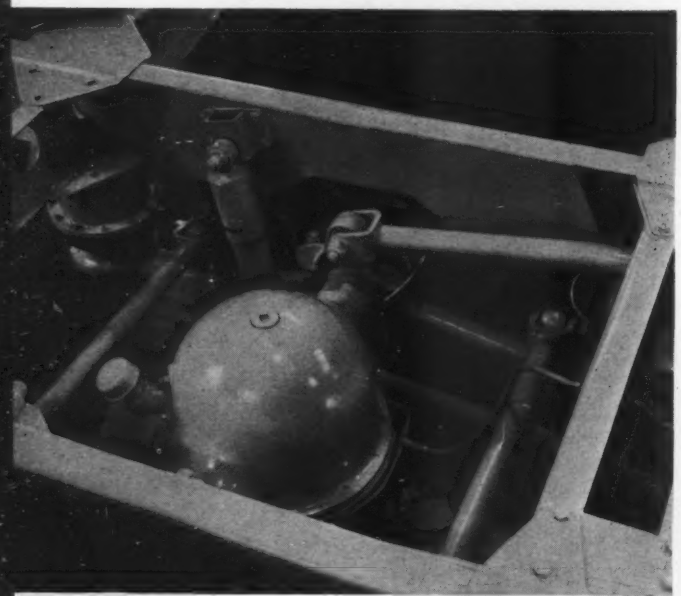


Fig. 11. Typical single-convolution air spring fitted to a Guy commercial chassis.

The Height Control System

Generally, four air springs will need controlling: this may be done by four, three or two height-control or levelling valves.

If four levelling valves are used, one for each bag, the whole of the chassis weight can be supported by two diagonally opposite air springs, while the chassis oscillates about the diagonal. This can be unpleasant.

If three levelling valves are used, two should be used to control the end of the chassis subject to greatest weight variation. The third should level the mid-point of the more

constant loaded end via an isolator valve to prevent cross flow between air springs.

If two valves are used, each levelling the mid-point of one end, there can be no anti-roll stiffness, and anti-roll bars become essential.

Height control valves fall into two classes, i.e., non-delay valves and time delay valves.

NON-DELAY VALVES—These valves are two-way valves which are opened by the relative movement between chassis and axle to pass a corrective air flow. They may be used either "locked out" or continuously operating.

The continuously operating valve, as the name implies, operates all the time. The duty of the valve seats is severe and there is a continual wastage of air.

The rate of flow from the air spring to exhaust depends on the spring pressure/atmospheric pressure ratio, while the rate of flow from the supply into the air spring depends on the supply pressure/spring pressure. The two are unlikely to coincide so that the vehicle will tend to subside or to pump itself up, because more air will be passed one way than the other. This feature may be overcome by controlling the supply pressure/spring pressure ratio by a reducing valve, but the initial simplicity of the non-delay valve is lost.

Reduction in air usage may be made by making the valve opening progressive with chassis movement, i.e. a small height error results in a small valve opening, a large height error results in a large valve opening. A snag arises, that to effect any real economy in air consumption the slow correction phase needs to be quite extensive. Thus a vehicle can swerve suddenly, resulting in fast correction of the tilt resulting, and when going straight again will have a tilt trapped-in, which will take some time to be removed by the slow correction phase.

The alternative method of employing non-delay valves is to interlock them so that they only operate intermittently. A popular interlock is with the doors, so that levelling only occurs when the doors are open, i.e., when a change of loading probably occurs. A fast levelling rate is therefore required. Since no controlling air flow occurs when the vehicle is moving, height change in the air springs cannot be corrected unless the driver has an over-riding control. The height change may be due to change of ambient temperature, fuel usage or dynamic heating of the air in the air spring. The over-riding control is also necessary to enable trapped errors to be removed. These occur because a tilt can result if levelling action occurs on uneven ground. It may also be used to give extra ground clearance if, in addition to permitting levelling action, the driver can admit air to all air springs.

While the control of air suspension appears at first sight a simple matter using a two-way valve for each air spring, it grows more complicated as the limitations of the simple valves are overcome.

The alternative approach, which has been widely adopted, is to use height control valves which have a delayed action. Their function is to permit the levelling action required only if the necessity persists for a definite time, and to ignore all departures in height of less duration.

TIME DELAY VALVES—Time delay valves are also two-way valves but the input signal is delayed before it actuates the valve. The common design is to store the input movement resulting from the alteration in chassis height in a spring and allow the stored energy to drive a hydraulically damped piston a short distance, at the end of which the piston or an extension to it contacts and opens the air valves. A time delay will result, depending on the spring rate, the degree of damping and the distance the piston has to move before reaching a valve. The delay is usually in the order of 5-10 seconds. The duration of the time delay is important; if too long the driver may have to wait before he can move off; if too short, levelling will occur during braking and acceleration and during cornering. Levelling due to cornering is particularly undesirable since, if a vehicle enters a curve and is levelled for centrifugal force and then makes a successive turn in the opposite direction, it may be very unstable.

There are some additional features of the hydraulic damped valve which distinguish it from the non-delay valve and are worthy of note.

It generally needs "lost-motion" in order to have a delay time; this is usually of the order of $\frac{1}{4}$ in. either side of the mean chassis height, and the valve will level the chassis within this band.

On some valves the time delay is a function of the chassis height error. The time delay is less as the chassis height error increases. This implies that a short duration but violent manœuvre may result in unwanted levelling action.

On some valves the damping effect is annulled during the

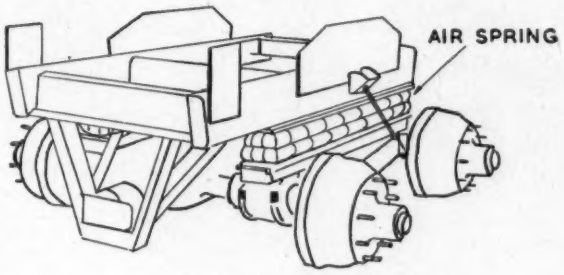


Fig. 12. Elongated air spring trailer bogie.

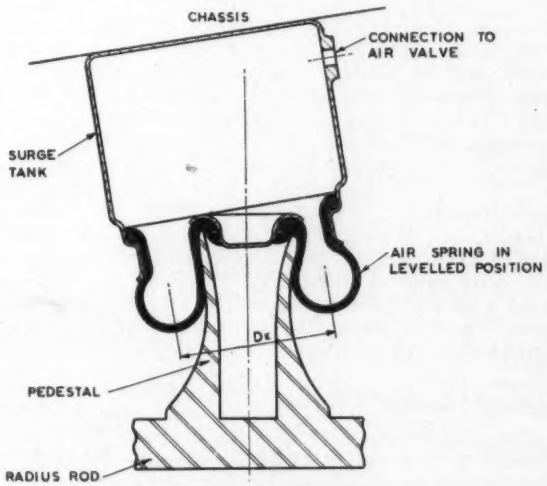


Fig. 13. Rolling lobe-type air spring.

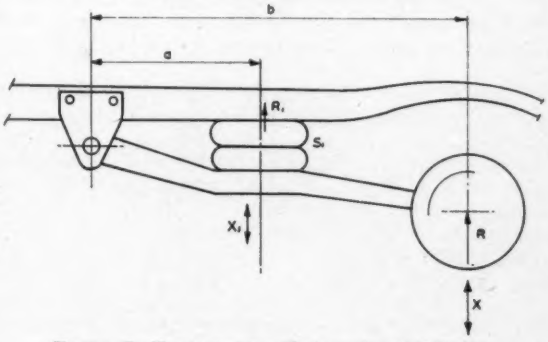


Fig. 14. Trailing-arm type of air spring installation.

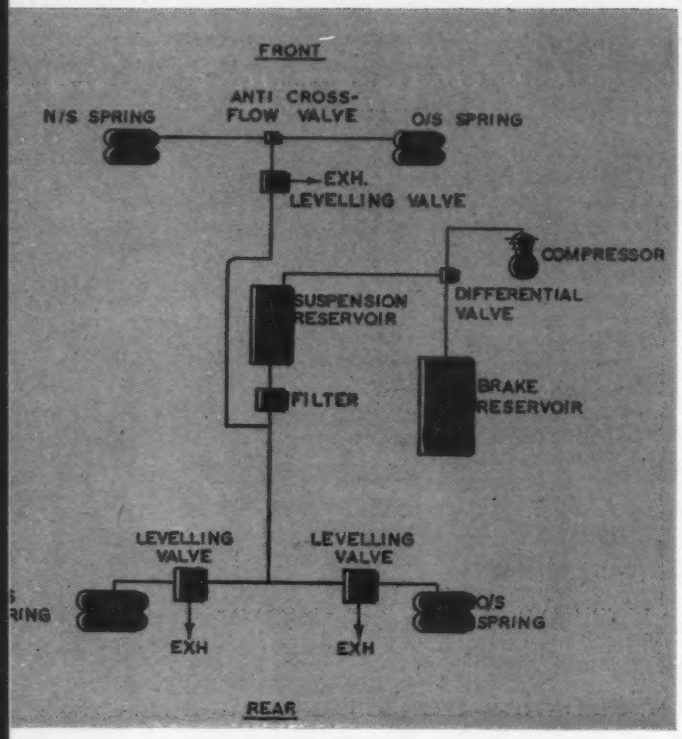


Fig. 15. Schematic layout for air suspension system.

resetting action. It will be appreciated that due to normal road irregularities the chassis-axle height varies continuously, and the piston of the hydraulically damped valve therefore oscillates at the same frequency as the chassis but with very reduced amplitude about a mean position. If a change of load occurs the mean position of the piston moves to correspond to the mean chassis height position. On valves where the damping effect is cancelled in the return-to-neutral direction of movement, the levelling accuracy can be affected by the oscillation of the vehicle, and in an extreme case where the load change results in a change in standing height equal to half the amplitude of road movement no levelling action on the move is possible. The time delay will be temperature sensitive, but means can be employed to overcome this.

The Air Supply System

The use of a time-delay valve enables a smaller air compressor to be used. On heavier commercial vehicles it is usual to use the compressor provided for compressed air braking for air suspension. If this is done it is important that the braking system has first choice of the available air. If no compressor is contemplated for braking, a small 1 or 2 c.f.m. free air delivery compressor has to be provided.

The compressor will supply air via an unloader valve to a reservoir. The reservoir has a relief valve and a drain valve. This is necessary because separation of the water present in the inducted air occurs here. The unloader valve should be preferably the delivery-unloader type.

The air springs are then piped to the reservoir via the levelling valves. If the levelling valves do not have inbuilt filters, a filter should be provided at the outlet from the reservoir.

The exhaust from the levelling valves may be to atmosphere or to a low-pressure reservoir, from which the compressor draws its air supply. The systems are known as "open" and "closed" systems respectively. Make-up air has to be provided for the closed system, so a valve has to be fitted to isolate the l.p. reservoir side from the compressor, and open the compressor intake to atmosphere when the l.p. reservoir pressure falls below the designed minimum. The closed system is more complicated than the open system, but offers slightly reduced power consumption. The open system has the advantages of simplicity and scavenging of the system.

Compressor Control—An air compressor running continuously will be doing more work than necessary. It is also prone to oiling-up of the valve gear. The pressure developed if air is not being used should be limited. This may be done by:

1. Blowing off excess air via a relief valve.
2. A balanced volume compressor, i.e., a compressor with a large ratio $\frac{\text{clearance at T.D.C.,}}{\text{stroke}}$ so that the peak pressure is limited.
3. A delivery unloader which, when the reservoir pressure is high enough, seals the reservoir from the compressor and simultaneously opens the compressor delivery to atmosphere, so that air is pumped through the compressor without appreciable pressure rise, and hence cools the machine.
4. A clutch knock-out device sensitive to reservoir pressure. A magnetic clutch could be used.

Both methods 2 and 3 are commonly in use. A comparison between an unloader controlled and a balanced volume controlled compressor of the same size is given in Fig. 9. The complete system as applied to a commercial vehicle is given in Fig. 15.

Future for Air Suspension

The advantages that air suspension confers are near constant low natural frequency and constant riding height.

To achieve these, equipment has to be carried which is not yet standard. The advantages offered are most apparent when there is a large variation in laden/unladen weight. This condition applies to the very light passenger car and to the p.s.v. and large truck. It is doubtful whether air suspension will be seen on the average car for some time. The commercial vehicle does benefit from air suspension, and American experience is that, in addition to saving in damage to freight, the maintenance costs of the vehicle are reduced considerably.

There is also the possibility of using the compressor necessary for the air suspension system to operate other devices, e.g., horn, windscreen wiper, etc., at present operated electrically, and for power actuation of brakes, clutch and gear shift.

It is not thought that there is an application for air suspension elsewhere than on vehicles, except where the vibrating mass varies widely. The United Co. of Philadelphia has, for example, embodied air springing on a prototype railway coach intended for inter-city travel.

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NEW METHOD OF MATERIALS SELECTION

SELECTING the best material for a particular design is never a straightforward procedure and must necessarily be a compromise between judgment based on experience and the direct requirements of certain physical and mechanical properties. Therefore, any method or system which assists in reducing the tedium of short-listing likely materials is welcomed by designers.

Material Data Ltd. have made considerable progress in developing a system that can be of immense help, and this has brought to light some surprising facts which illustrate how materials hitherto accepted as being the most suitable are not necessarily the best.

The system is based on the calculation of ratios of such properties as weight, strength, cost and thermal conductivity, and lists them in order of merit (see table below). With these lists a designer can see at a glance the advantages or otherwise that may be obtained by a change of material. The merit index, together with all relevant information is computed and issued in the form of a punched card.

The value of this system is best illustrated by a simple example to decide which is the cheaper material for a component that has to resist tensile loads only:

Material A	Strength, f	250,000 p.s.i.
	Density, w	9·34 gm./cm.^{3}
	Cost, c_w	£450 per ton
Material B	Strength, f	17,000 p.s.i.
	Density, w	1·97 gm./cm.^{3}
	Cost, c_v	63s. per ft.^{3}

Using the merit indices c_v/f equals 0·000056 units for material A and c_v/f equals 0·000022 units for material B, thus with the criterion mentioned material A is approximately two-and-a-half times as expensive as material B.

The merit indices are conveniently arranged in three major parts, i.e., (1) mainly mechanical properties, (2) mainly electrical and thermal properties, and (3) combined mechanical, electrical and thermal properties. These are further subdivided into specific quantities:

1. MAINLY MECHANICAL

Density	w
Weight cost	c_w
Specific heat	c_p
Thermal expansion	a
Maximum strength/minimum volume ...	1/f
Maximum strength/minimum weight	w/f
Maximum strength/minimum cost	c_v/f
Maximum stiffness/minimum volume	1/E
Maximum stiffness/minimum weight	w/E
Maximum stiffness/minimum cost	c_v/E
Maximum bending strength/minimum weight	$w/f^{\frac{1}{2}}$
Maximum bending strength/minimum cost ...	$c_v/f^{\frac{1}{2}}$
Maximum bending stiffness/minimum weight	$w/E^{\frac{1}{2}}$
Maximum bending stiffness/minimum cost ...	$c_v/E^{\frac{1}{2}}$

2. ELECTRICAL AND THERMAL

Minimum heat transfer/minimum volume ...	k
Minimum heat transfer/minimum weight ...	wk
Minimum heat transfer/minimum cost ...	c_v/k
Maximum heat transfer/minimum weight ...	w/k
Maximum heat transfer/minimum cost ...	c_v/k
Maximum current transfer/minimum volume	R
Maximum current transfer/minimum weight	wR
Maximum current transfer/minimum cost ...	c_vR
Minimum current transfer/minimum weight ...	w/R
Minimum current transfer/minimum cost ...	c_v/R
Maximum strength/minimum heat transfer along rod or in plane of sheet	k/f
Maximum stiffness/minimum heat transfer along rod or in plane of sheet	k/E

3. COMBINED PROPERTIES

Maximum bending strength/minimum heat transfer along rod or in plane of sheet ...	$k/f^{\frac{1}{2}}$
Maximum bending stiffness/minimum heat transfer along rod or in plane of sheet ...	$k/E^{\frac{1}{2}}$
Maximum strength/maximum heat transfer through sheet	1/kf
Maximum stiffness/maximum heat transfer through sheet	1/kE
Maximum bending stiffness/maximum heat transfer through sheet	$1/kE^{\frac{1}{2}}$
Maximum strength/ minimum current transfer along rod or in plane of sheet	1/Rf
Maximum stiffness/minimum current transfer along rod or in plane of sheet	1/RE
Maximum bending strength/minimum current transfer along rod or in plane of sheet ...	$1/Rf^{\frac{1}{2}}$
Maximum bending stiffness/minimum current transfer along rod or in plane of sheet ...	$1/RE^{\frac{1}{2}}$
Maximum current transfer along rod/minimum heat transfer along rod	kR
Thermal diffusivity	k/wc_p
Minimum heating rate in material under application of unit potential	$1/Rwc_p$

Ninety-six different materials have been reduced to merit indices, ranging from cement and concrete to laminated fibres and from felts to metals in common use. In addition to this wide coverage, a reliability code is incorporated to differentiate between properties known to be accurate and those which are approximate. The lists are kept up-to-date and distributed to members for a very reasonable subscription rate. Various modifications to the method of tabulation are currently being made.

1001	AL BRONZE	CANNING	CENTRAL 8121	4747—02 11
1070	HIDUMINIUM RR58 FORGED	HIGH DUTY	SLOUGH 23901	+5078—02
1010	SODA GLASS	BTH	TEMPLE BAR 8040	+5210—02 13
1048	COPPER TOUGH PITCH	ENTORES	MONARCH 3415	+5291—02
1049	COPPER TOUGH PITCH 250C	ENTORES	MONARCH 3415	+5291—02
1092	JESSOP H40 STEEL	JESSOP	SHEFFIELD 41352	+5714—02
1065	PHOSPHOR BRONZE	JMC	HOLBORN 6989	+6094—02
1089	MAGNESIUM Z5Z DTD 721A	MAG ELEK	WHITEHALL 1040	+6613—02
1090	MAGNESIUM DTD000M40	MAG ELEK	WHITEHALL 1040	+6613—02
1016	POLYESTER CAST	MITCHELL	MITCHAM 4684	+7936—02 13
1024	STEEL STAINLESS EN58E	FIRTH BROWN	SHEFFIELD 20081	+9259—02 13

Typical tabulated selection data, with merit indices at right, obtained from computer.

designer's notebook

Problems of Overhang and Guided Length

ONE of the commonest, as well as the most serious, faults in design is the neglect of elementary principles of geometry in the way in which parts are held in position or constrained in motion. This often shows itself in an inadequate "length to width ratio" or ratio of "overhang to guided length". It is equally common in light instrument work and in heavier machinery. Any element or part has six possible degrees of freedom of motion, sliding along any of three axes mutually at right angles, or rotating about these same axes, or any combinations of these motions. The customary convention will be used where the X axis (see Fig. 2) is a horizontal line in the plane of the paper, the Y axis is a vertical line in the plane of the paper, and the Z axis is at right angles to the plane of the paper.

The simplest case is probably a fixed block with a vertical hole in it into which a closely fitting circular rod can be inserted. Fig. 1(a) shows the lower end of the rod just entered, giving positional constraint in the X and Z axes to the lower end of the rod, but otherwise allowing complete freedom. As the depth of entry is increased, as at (b) and (c), the constraints become more and more complete, ultimately leaving only freedom of sliding in and rotating about the Y axis. The quality of the constraint as affected by the overhang to guided length ratio, O/L, and the length to width ratio, L/W, is immediately apparent, particularly as affecting freedom of rotation when subject to a force on the overhung portion in the X or Z planes.

If a flat strip instead of a circular rod is considered, fitting into a correspondingly shaped hole, these ratios become more apparent. It is easy to see, in Fig. 2, that a depth of entry which would give quite good constraint against rotation about the X axis might be quite inadequate as regards rotation about the Z axis. The length of entry should be substantially greater than the width or the overhang, how much so will depend on a number of conditions.

It seems absurd to call attention to such simple and obvious points, but they are only too often neglected. Some examples of these and other points to watch are given. Fig. 3, for example, is a slide block carrying a pin which is required to move parallel to itself. The overhang to length ratio needs to be very carefully watched, in both directions, as well as the stiffness of the guide rails. If the width (W) is not enough, the turning couple on the slide block may cause such pressure on the rails as to prevent free sliding, and the more force applied the tighter it jams.

Fig. 4 shows a very common fault, usually easy to correct. With a bad overhang ratio any play in the bearings appears in an exaggerated form as backlash in the gear train. Fig. 5 shows a double fault—also only too common—superfluous constraints, and a bad overhang ratio. The double guide bar of (a) is poor. Much better to use one—longer—main guide bar, and only a tail guide for the end of the slide.

The bearings of a rotating member must have plenty of either length or diameter: a single bearing as at (a) in Fig. 6 may be quite adequate if the diameter is good enough, but if two bearings are fitted there must be adequate length between them. A "square" bearing (length equal to diameter) should be suspect. It is not necessarily bad, but if the load is overhung it may prove the worst of all possible arrangements. Similar principles apply to fixing a pinion to a shaft. The hub must have diameter or length, and a good ratio between them; a toothed rim is fixed to a disc wheel by diameter only, but the hub is secured to the shaft most frequently by length. Fig. 7 shows a plain block sliding in a groove, as for guiding the end of a link. The length should be greater than the width, or it may tend to jam up, although there are no definite forces tending to make it do so.

Design faults of these kinds are often not too easy to see in a complete general arrangement drawing. The trivial may obscure the essential; for example, an oil seal may give the impression that a shaft—as in Fig. 4—may be well supported quite close to the gear wheel, whereas there is really nothing there at all. It may be necessary to make a special drawing in which all the frills are left out and only the bare essentials left, in order to show clearly which members carry which stresses, and how. These and other design faults are usually only explicable in terms of drawings, not only of the particular element in question. Consideration of the whole gear train involved may be necessary, both as a whole and in every single detail. These matters cannot be adequately discussed or dealt with in words; drawings, involving many alternative layouts, are usually involved before a good all-round solution appears.

H. Clausen, O.B.E., I.S.O., B.Sc. (Eng.)

DESIGN BUREAU

Do you have a design problem? Or a solution to somebody else's problem? We are frequently asked to provide the solution when readers come against difficulty in producing a satisfactory mechanism.

From time to time, DESIGNER'S NOTEBOOK will feature readers' solutions to specific design problems, the best submitted to this office being published. Solutions should embody original ideas, or should otherwise acknowledge the source.

Contributions, which will be paid for if used, should be sent to The Editor, E.M.&D., marked "Design Bureau (July)".

THIS MONTH'S PROBLEM

To provide a simple means of mechanical reciprocation with adjustable dwell at each end of the stroke.

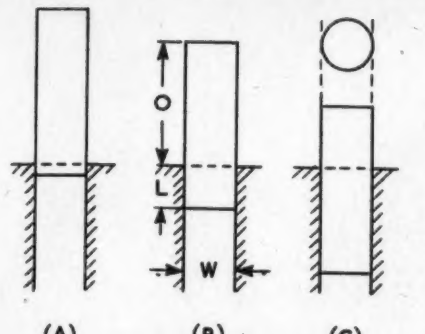


FIG. 1

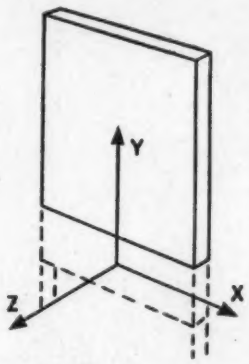
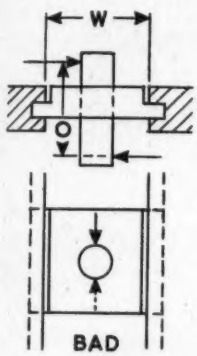


FIG. 2



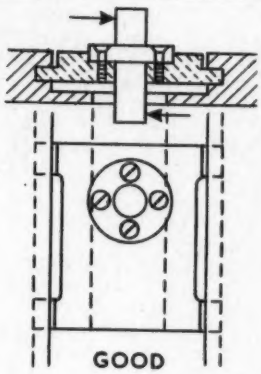
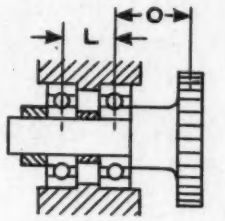


FIG. 3



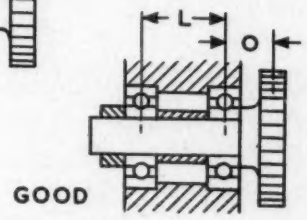
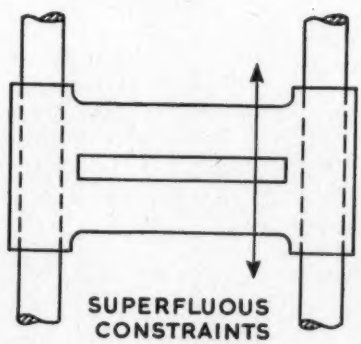


FIG. 4



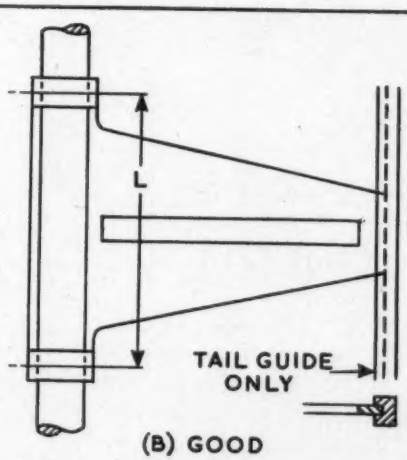


FIG. 5

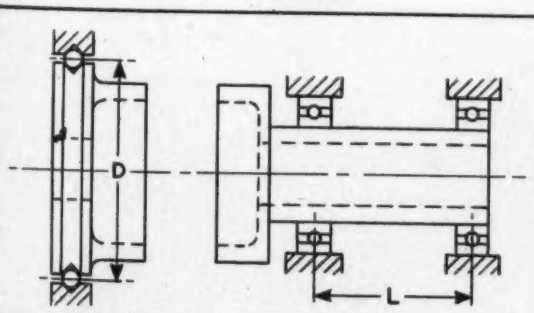


FIG. 6

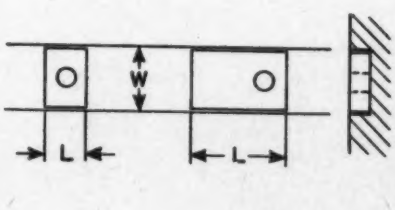
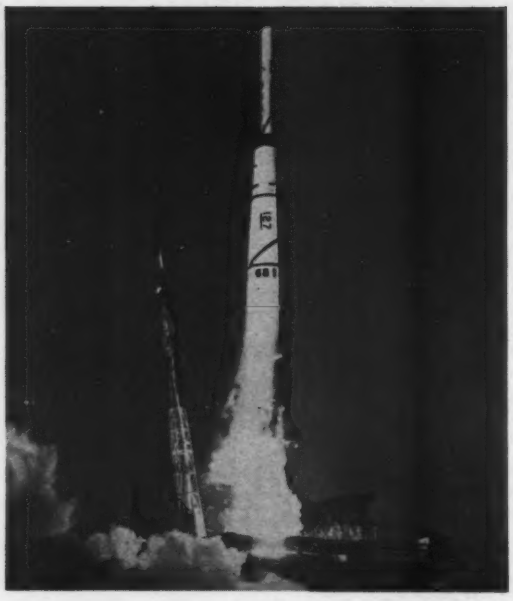


FIG. 7



U.S. Air Force lunar probe vehicle using a combination of liquid and solid fuels. (Photo: Aerojet-General Corp.)

DESIGN PROBLEMS WITH BORON FUELS

Boron has a dual role in structural materials or propulsive media in engineering. The latter application is discussed here, together with its performance and characteristics and the special handling factors that are encountered in its use

by E. M. GOODGER, M.Sc. (Eng.), Ph.D., A.M.I.Mech.E., A.F.R.Ae.S., F.Inst.Pet.*

As chemically-propelled vehicles derive their propulsive thrust from the chemical reaction of their propellents, a high reactive energy is the first essential. With most air-breathing engines, it is sufficient to assess this suitability from a knowledge of the energy content of the fuel, expressed in terms of the heating value per unit mass or per unit volume. In airborne vehicles, mass is a vital factor, and the maximum heating value per pound of fuel is the target. In the case of piston-engined aircraft, the engine exerts an overriding requirement upon fuel type, and gasoline fuels of high anti-knock quality are essential. However, reference to Fig. 1 shows that these fuels also exhibit the highest heating value/lb. for all the petroleum-type liquid fuels available. Hence, gasolines satisfy both engine and aircraft-loading requirements.

With the advent of the high-speed turbojet fighter aircraft, the heating value/gallon has become equally significant, since aerodynamic design stipulates thin wing sections and these restrict fuel stowage space. Fig. 1 shows that heating value/lb decreases with the heavier petroleum fuels, whereas heating value/gallon increases. The volume-limited turbojet fighter aircraft would therefore be more suited to a kerosene or even a gas oil, rather than a gasoline, since anti-knock quality is of no consequence here. Gas oils cannot be widely used, however, because of freezing difficulties. Generally, both forms of expressing energy content are important for high-speed aircraft equipped with air-breathing propulsive units, and this has led to the derivation of a "performance index", expressed as the ratio between the products of these two heating values (Centigrade Heat Units) for the fuel in question and for aviation kerosene, i.e.,

$$\text{Performance index} = \frac{\text{c.h.u./lb.} \times \text{c.h.u./gallon}}{K}$$

where K for aviation kerosene is 840×10^6 approximately, in consistent units.

Aviation kerosene is a mixture of many hydrocarbons, and inspection shows that carbon contributes about 86 per cent of the mass of the fuel, yet only 62 per cent of the energy. It is logical, therefore, to investigate alternative elements which will combine with hydrogen to form conveniently-handled liquids, yet release more energy on combustion. Both boron, a non-metal, and lithium, an alkali metal, form hydrides, but only the former has an energy content higher than that of kerosene.

The boron hydrides (i.e., boranes) of interest as potential fuels include diborane (B_2H_6), pentaborane (B_5H_9) and decaborane ($B_{10}H_{14}$). The heating values of boron and the boranes are shown in Fig. 2, and these indicate dramatically the improvements over conventional fuels. These advantages reappear when comparing on the combined basis of the performance index, as shown in Fig. 3. Boron, for example, exhibits a gain of more than 400 per cent over aviation kerosene.

With rocket engines, oxygen is supplied by means of an oxidant carried on board; hence there is no restriction to the natural oxygen content of atmospheric air, and either oxygen-rich materials or pure oxygen itself may be used.

* *Senior lecturer, department of aircraft propulsion, College of Aeronautics, Cranfield.*

In the absence of nitrogen as a diluent, combustion temperatures are of the order of 3,000 deg. C. or more, instead of the 2,000 deg. C. met in most air-breathing engines. The same reasoning applies, to a lesser extent, with high-temperature rich-mixture operation in ramjets and reheat chambers. The picture is now complicated by the thermodynamic behaviour of the combustion gases in their passage through the propelling nozzle. Since thermodynamic data under exit conditions are available, exit velocities can be calculated, together with the resulting thrust. These parameters form the only realistic bases for the comparison of performance, although relative values of heating value or performance index are useful in the first instance.

The overall thermodynamic suitability of rocket propellents may be expressed in terms of the thrust produced by the consumption of unit mass of propellents per second, i.e., the "specific impulse", in units of Lb./lb.* per second, or Lb.second/lb. The range of specific impulse values currently available with conventional fuels and oxidants is in the region of 200 to 300 Lb.second/lb. A diborane-fluorine combination would increase this to at least 310 Lb.second/lb. An upper limit of 370 Lb.second/lb. is reached for chemical propellents with the combination of hydrogen and ozone, but the handling problems with both these materials are prodigious.

The operating range of a rocket-propelled vehicle is a function of the square of the specific impulse; hence any improvements incurred in specific impulse are markedly attractive for a long-range vehicle.

With boron fuels, combustion temperatures are at least 400 deg. C. higher than those obtained with conventional fuels, which increases the significance of the thermodynamic effects, as well as the magnitude of the design problems. Boron compounds burn with relatively high flame speeds, which permits higher entry speeds into the combustion chamber, and shorter chamber lengths. This factor is particularly important in the ramjet engine, where the length of the combustion chamber is a major portion of the whole. The higher reactivity of the fuel also permits engine operation at more extreme altitudes.

Two forms of deposition trouble are likely to occur in the combustion chamber of a boron-fuelled engine. Solid products result from thermal decomposition of the liquid fuel, and these tend to collect in the region of the fuel injectors, and to disturb the flow patterns. Secondly, boranes burn to boric oxide (B_2O_3) which, above about 550 deg. C., is a viscous syrupy liquid. This collects on the hot internal surfaces of the engine and flows past the downstream components. At temperatures below 550 deg. C., boric oxide sets to a hard, glassy solid, which is erosive. This tends to rule out applications to turbojet engines, except for reheat purposes downstream of the turbine.

Handling

For ease of handling, fuels should exist in the liquid phase at normal temperatures, since gaseous fuels call for pressurised containers which are heavy and bulky, and solid fuels are difficult to pump. Fuels should be pure, inert and stable, with no physiological hazards. In addition, they should be easily available and inexpensive. Conventional fuels meet these requirements to a greater or lesser degree, but difficulties are encountered when new fuels of promising performance are measured against these standards.

Elemental boron, isolated in 1808, is a solid, and exists in nature mainly in the oxide form as a borate. This is also the resultant combustion product, which means that energy must be added during the processing in order to de-oxidise the borate to boron, ready for re-oxidation in the combustion chamber. This helps to keep the cost of boron high.

Laboratory quantities of pulverised boron cost from £8 to £28 per lb., depending upon purity, and whether amorphous or crystalline, as against 2½d. per lb. for aviation kerosene. The energy content of 1 lb. of kerosene is equal to that of 0·73 lb. of boron, which—at the above price rating—would cost from about £6 to £20. These prices would be expected to fall with increased production.

Diborane, pentaborane and decaborane exist in the gaseous, liquid and solid states respectively at normal temperatures. Diborane condenses at −92 deg. C., pentaborane freezes at −46·7 deg. C. and boils at 63 deg. C., whereas decaborane melts at 99·4 deg. C. Boron itself melts at about 2,200 deg. C.

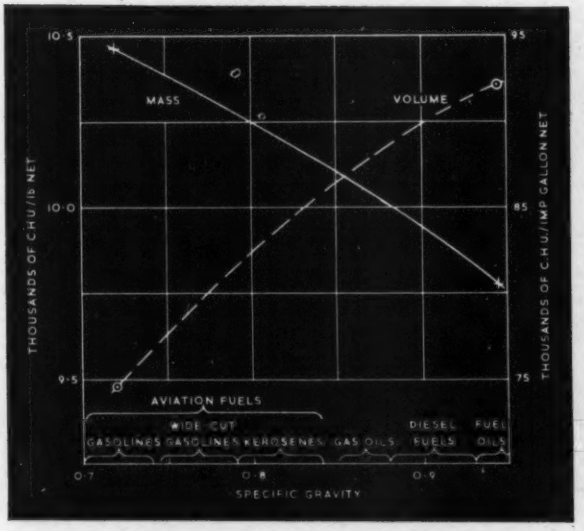


Fig. 1. Heating values of conventional petroleum fuels.

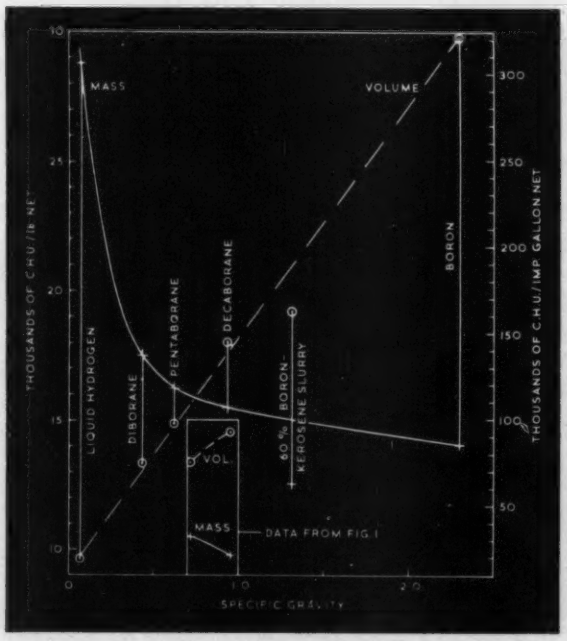


Fig. 2. Heating values of boron fuels.

* Units to Stroud convention.

Gaseous diborane ignites spontaneously in air, and is readily explosive. Its violent reaction in the presence of moisture makes handling difficult, but offers possibilities of underwater propulsion. As with many boron compounds, diborane has a disagreeable odour and is toxic.

As a liquid fuel, pentaborane is more attractive from the handling viewpoint. It does not ignite spontaneously in air when cool, but it may explode when hot. It is liable to decompose on standing, giving off hydrogen gas and forming heavier boranes which are solid but dissolve in the parent pentaborane. This decomposition is still slow in the presence of moisture, and results in boric acid. Pentaborane is also toxic. Decaborane is solid and has a lower performance, but it is less toxic and has a low vapour pressure.

In view of the severe problems involved with the projected use of the boranes, a valuable expedient is the compounding of carbon with boranes to produce carboboranes. The carbon is added in the form of alkyl groups, such as the ethyl radical. Performance suffers slightly, but alkylation creates a stabilising effect and reduces the toxicity of the combustion gases. In America, the Olin-Mathieson Chemical Corp. produces carboboranes under the designation HEF, i.e., high energy fuels, whereas the Callery Chemical Co. designation is HiCal.

In ramjet applications, fuels of a pyrophoric (spontaneously ignitable in air) nature are attractive, since their inflammable mixture range is much wider than that of hydrocarbon fuels, and they burn at lower mixture pressures. These properties permit the use of smaller, lighter and more reliable ramjets, capable of economic high-speed operation at very high altitudes. They may also be used as turbojet ignition fluids, and as anti-screech additives in rocket engines. The pyrophoric nature of some boron compounds, although giving rise to handling difficulties, is attractive performance-wise, and tests are proceeding with triethyl borane (TEB), as well as triethyl aluminium (TEA) and trimethyl aluminium (TMA).

Solid Fuels and Propellents

The solid state is the most compact form for most materials, and high heating values/unit volume are exhibited by elemental boron and other solids. The principal handling difficulty lies in transference from storage tank to combustion chamber. The solid may be made pumpable by pulverising to a fine powder and then either aerating or suspending in a liquid as a paint-like slurry. The latter method is more attractive, since a suitable fuel can be chosen as the supporting liquid. The heating values of a theoretical slurry of 60 per cent by mass of boron in aviation kerosene are included in Figs. 2 and 3. This represents about the maximum boron content permitted from pumpability considerations. Additional problems likely to arise when using boron in the slurry form are as follows:

1. Settlement of the pulverised boron. Additives are available to assist suspension, but they are likely to augment blockage troubles at low temperatures. A vibratory system would also assist, but might accelerate airframe fatigue troubles.

2. Abrasion of the fuel system. Boron is second only to diamond in hardness. Special designs of fuel pumps and systems would be necessary to meet this difficulty

3. Differences between combustion characteristics of the solid and liquid portions. Care must be taken to ensure that each can burn effectively in the presence of the other, so that the full energy potential can be realised.

An alternative approach is to prepare an intimate mixture of fuel and oxidant, cast as a solid block of monopropellent. This makes for engineering simplicity and reliability, but the performance is generally lower, and combustion cannot be controlled manually. Unstable burning, due to cracks formed by the high-temperature gradients, has been largely overcome by the development of plastic propellents incorporating rubber-like materials. Here, again, boron offers improvements in propellent performance, and a high-energy solid boron-type monopropellent is being developed jointly by the Thiokol Chemical Corp. and the Callery Chemical Co. in the U.S.A.

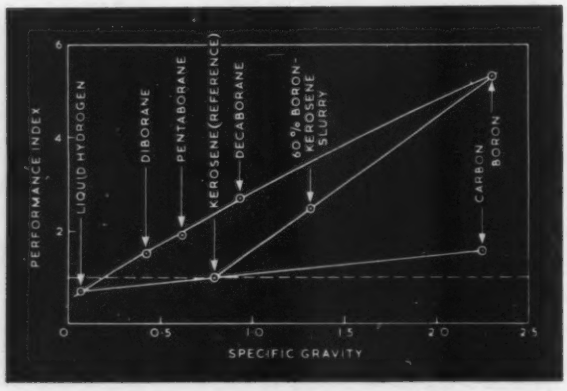


Fig. 3. Performance index values.

Design Factors

Little unclassified data have appeared at this stage to indicate in detail those materials which are, or are not, compatible with boron and its compounds, but it appears that most structural metals are suitable, with the possible exception of lead and copper. Welded construction is recommended.

In the combustion chamber choice of manufacturing materials will be dictated by three factors: high combustion temperature, tendency to deposit accretion, and abrasion. These problems are acute, but they may be alleviated to some extent by careful design. Film cooling of the chamber walls, for example, reduces high temperature problems, and increased knowledge on the mechanism of deposit formation will serve as a guide towards desirable levels of temperature and types of material. Nevertheless, the development of new alloys will probably be necessary together with a wider use of ceramic coatings.

In the storage tank, exclusion of air and water will be necessary, together with the absence of high temperatures, in order to restrict decomposition. In some cases a dry inert gas such as nitrogen or argon may be applicable for safety purposes. In static installations, the toxic vent gases will need to be scrubbed or destroyed. Since hydrogen gas is released upon decomposition, mild steel and other materials subject to hydrogen embrittlement cannot be used, and non-return relief valves must be incorporated. Either centrifugal or positive-displacement pumps should be satisfactory for borane fuels, but abrasive wear would be a major problem with boron slurries. All seals must be entirely leakproof. Rubbers and other organic materials would not be suitable, in view of possible instability, so that seals, seatings, hoses and diaphragms might call for selected plastics.

The general framework above can be filled in, and extended, as and when further details on these materials are discovered and released. All this represents a sizeable collection of problems, and considerable expense is likely before solution is achieved. The stimulating thought is that propulsion technology has now reached the stage where it is almost wholly dependent upon propellents for a major advance, and that almost any price must be afforded in order to maintain immunity from the crippling attacks possible by a mere handful of missiles.

DESIGN ENGINEERING CONFERENCE

Selections from some "materials" papers read at the recent design conference in Philadelphia

LATEST DEVELOPMENTS IN MATERIALS TO RESIST CHEMICAL CORROSION. *By Spencer W. Shepard*

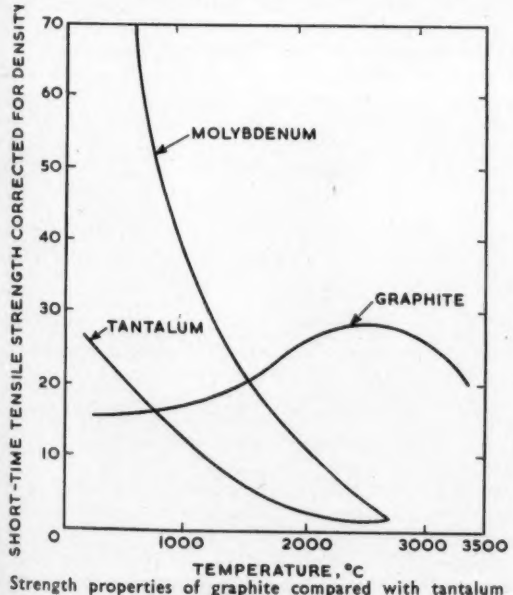
In recent years there have not been many totally new materials for corrosion resistance, but there have been many improvements in existing materials and many developments in new forms, new combinations and increased availability of these materials. In the field of aluminium and its alloys there are now available new and stronger corrosion-resistant alloys with improved weldability.

The precipitation hardening stainless steels and the stainless steel substituting manganese for nickel have been further developed to give higher strengths and increased hardening, without loss in corrosion resistance, by a simple heat treatment. Considerable technical development has taken place in titanium and its alloys, and it has been developed for use in honeycomb structures and many other specialised requirements for the chemical industry. In the field of non-ferrous metals an automatic lead-burning machine has been developed for cladding steel vessels with lead up to $\frac{3}{16}$ in. thick. The use of this machine is said to reduce the cost to about one-fifth of conventional hand-burning methods. The applications of plastics and rubbers have widened considerably, particularly when used as coating materials. There has been evidence of an increasing use of the application of powdered plastics to pre-heated metals by the fluidised-bed process. Ceramics and glasses have considerably widened their scope and the development of plasma torches has been used to apply hard facing materials which were too refractory for normal flame-plating methods.

NEW DEVELOPMENTS IN METALS AND CERAMICS FOR HIGH-TEMPERATURE SERVICE. *By J. J. Harwood*

Activity in the field of rockets, high-speed aircraft and nuclear power systems has influenced research into new and improved materials for high-temperature operation.

Titanium alloys are becoming important for temperatures up to 650 deg. C. and intermittently up to 800 deg. C. Although they possess a high strength-to-weight ratio, their alloys at present only retain their strength up to 45 per cent of their melting point and therefore there is scope for considerable further development. The high modulus and melting point of beryllium have aroused much interest in this metal and particular emphasis is being placed on research to overcome low ductility and brittleness.



Strength properties of graphite compared with tantalum and molybdenum.

TABLE 1. Refractory metals

	Melting point, deg. C.	Density, g./cc.	Young's modulus, 10^6 p.s.i.
Tungsten	3,410	19·3	50
Rhenium	3,180	20·0	67
Tantalum	2,996	16·6	27
Osmium	2,700	22·5	80
Molybdenum	2,625	10·2	45
Ruthenium	2,500	12·2	—
Iridium	2,454	22·5	75
Niobium	2,415	8·57	15
Rhodium	1,966	12·4	41
Chromium	1,890	7·19	36

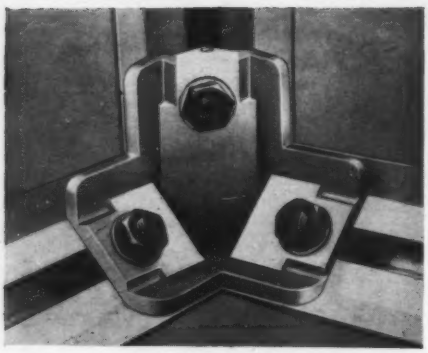
The refractory metals such as molybdenum and tungsten are undergoing intensive development, and alloys are being obtained with outstanding strength at temperatures up to 1,000 deg. C. and higher. It is possible that alloys having tensile strength of 100,000 p.s.i. at 1,000 deg. C. may yet be obtained. One of the biggest problems is oxidation resistance and, although some resistant alloys have been produced, it is not easy to combine this property with ease of fabrication. Much attention has been concentrated on cermets and ceramics for high-temperature use, but one of the most interesting recent events has been the demonstration of a degree of ductility in certain ionic solids and oxides. Graphite is also being examined on account of its high sublimation temperature (about 4,000 deg. C.) and because it has strength superior even to the refractory alloys above 2,500 deg. C. The major drawbacks are poor oxidation and erosion resistance, but attempts are being made to overcome these by using silicide or carbide coatings. (See table.)

RECENT DEVELOPMENTS IN MATERIALS AND FINISHES TO RESIST ATMOSPHERIC CORROSION. *By E. B. Friedl, L. J. Nowacki, W. H. Safranek*

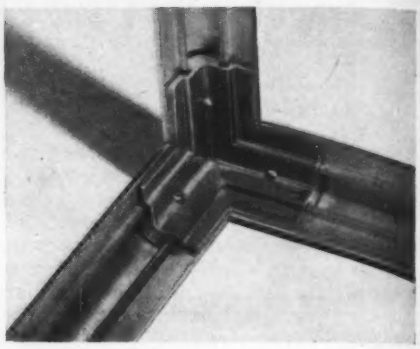
No revolutionary developments in new materials appear to have taken place during the last few years, but there has been a growing appreciation of the importance of proper application procedures and adequate thickness of protective coatings. Also, there has been universal emphasis on designs to take into account maintenance painting, by eliminating sharp edges and re-entrant angles as well as by the use of welding to replace riveting. In the field of paints the use of epoxy resins has continued to grow on account of their excellent chemical resistance. Recent developments in alkyds have led to improved hardness, drying speed, and water and alkali resistance.

In automobile engineering there has been a trend towards acrylic lacquers, because of the improved durability and gloss retention, compared to nitrocellulose lacquers. Polyurethane coatings are also being developed for special applications, including chemical or abrasion resistance.

Improved procedures for electro-deposit coatings include (1) a bright crack-free chromium plating, said to have superior corrosion resistance to normal chromium plating; (2) Duplex nickel coating, which consists of a layer of passive, not-fully-bright nickel followed by a second layer of bright nickel; and (3) bronze (80 per cent Cu, 20 per cent Sn) plating which performs like the inside layer of the Duplex nickel and is usually overplated with nickel or chromium.



Two methods of internal corner fixing. Left: Widney Dorlec system of single-bolt fixing, which can be used for fitting equipment in an electronics cabinet. Right: An Imlok corner casting assembled in the frame extrusions of a cabinet.



CONSTRUCTIONAL FRAMEWORKS AND SYSTEMS

This article describes some of the many ranges of quick assembly construction kits that have become available to the designer, and how they may be of benefit in product design and experimental work

by MOLLY NEAL, B.Sc., D.I.C., A.F.R.Ae.S.

FOR more than fifty years, constructional kits for model-making have been available to boys, and such versatile playthings as Meccano have been used to quite a large extent for serious work in laboratories. Industry generally, however, was slow to exploit the possibilities revealed by the toymakers, and it was not until after the Second World War that full-scale kits of parts for quick assembly were put on the market. They achieved rapid success, and today there is a profusion of "build-it-yourself" kits for structural, storage and experimental purposes.

Probably the most widely used type of structural material is slotted angle, for which applications include storage units, work benches, maintenance platforms, test rigs, and so forth. It is available for light, medium or heavy duties and can be readily built up into more complex sections such as I-, T-, or box sections, for greater strength and rigidity. The kits usually comprise about 100 ft. of angle in 10- or 12-ft. lengths, with nuts and bolts, and customers cut the angle to length to suit themselves. Most makers supply a quick-cutting tool for this purpose. Usually a range of accessories is available, such as cleats and gusset plates, panels lipped and slotted for ready assembly to a slotted angle frame, hinges, castors and wheels, glazing strip, etc. Details of some of the principal types of slotted angle are given in Table 1.

Other forms of structural framework of this kind, listed below and illustrated, include (1) special forms of clamps for quickly securing steel tubes together to form storage racks or more complex structures; (2) a heavy-duty unperforated steel channel with an ingenious self-locating nut assembly, which can be embedded in concrete to form the foundation for a quickly erected steel frame building, as well as being used for more conventional racking systems; and (3) a system of perforated frames and struts specially devised for building up aircraft ground-servicing and other temporary structures to particular requirements.

Under the heading "Working Model Kits" will be found details of an elegant system of Swedish origin, from which extremely complex models and prototype machines can be built.

The example illustrated is a fairly simple element which shows clearly some of the basic components of the system.

For the electronics and instrumentation engineer, prefabricated "breadboard" kits are now available for building experimental set-ups rapidly and with the minimum of labour, as well as parts for constructing cabinets, racks, switchboards and instrumentation cubicles. Two of these cabinet systems make use of specially designed extrusions and corner castings, which are available in a wide variety and permit a large number of cabinet and console shapes, both straight and slope-fronted, to be built up on a quickly-erected framework to which sheet-metal panels can be secured flush by set screws. These also are listed at the end of the article.

Slotted Angle

The various ranges of slotted angle available are summarised in Table 1.

Heavy Constructions

SANKEY-SHELDON LTD. (UNISTRUT)—Heavy-duty framing and support system. Comprises basically unpierced channel section secured by self-locating nut assembly to connecting fittings. Supplied to order in basic channel form or in a variety of welded combinations to give sturdy built-up sections.

Material. Cold-rolled steel. *Finish.* Stove-enamelled or galvanised. *Dimensions* of basic channels: $1\frac{5}{8} \times 1\frac{5}{8}$ in. × 12 s.w.g.; $1\frac{5}{8} \times 1\frac{5}{16}$ in × 16 s.w.g.

Fittings include connecting angles, T's, flat plates, U-supports, Z-supports, cup-supports, clamps for attaching I-beams to Unistrut, pipe clamps for pipes from $\frac{1}{4}$ to 8 in.

bore, suspension members, closer strips, end caps, swivel joint plates, etc.

Concrete inserts. Lengths of Unistrut channel with end caps and anchor lugs for securing to shuttering before pouring, so that insert will be embedded flush in concrete, with continuous open slots in which Unistrut nuts can be inserted.

Tubular Constructions

FISHER & LUDLOW LTD. (FLOWCLAMP)—Simple clamping system for joining horizontal tubes to upright tubes, without need to drill holes in the tubing. Cast-iron clamps, designed for use with 1-in. bore tubing, supplied in lengths to order.

GEO. H. GASCOIGNE CO. LTD. (KEE KLAMP)—Versatile clamping system for varied tubular structures. Grub screw operated by detachable key secures each tubular member to the Kee Klamp sleeve coupling.

Over thirty types of Kee Klamp available, including T's, elbows, cross-joints, cross-over joints, combination T and cross-over joints, swivel sockets, flanges, etc., with provision for 30, 45, 60, 90, and 120 deg. angle joints.

Sizes. Kee Klamps are for use with tubes cut to exact length, in nominal bore sizes ⅜, ½, ¾, 1, 1¼, 1½ and 2 in. Steel tubes, galvanised or self-colour, supplied to order.

Accessories. Kee Boards—panel units flanged and shaped to fit over tubular members, in 5, 6 or 7 in. depths and spans from 1-5 ft.

Working Model Kits

WEYCO (SALES) LTD. (FAC)—Self-contained set of standard elements for assembly into working models for experimental or demonstration purposes. Available in "minor industrial" and "major industrial" sizes—the latter very comprehensive with 4,670 parts.

Based on 7-mm. module.

Structural Elements. These comprise round steel rods and strip metal beams with formed tubular flanges, clamped together by couplings secured by bolt and nut; also screwed-end rods coupled by threaded sleeves.

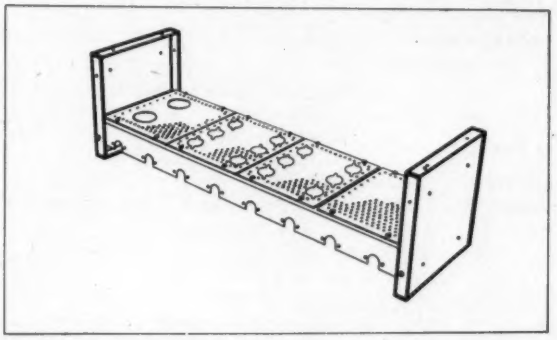
All rods 4 mm. dia. All threads 3 mm. Metric. Shafting 4 or 6 mm. dia. Beams and flat plates perforated with slots 14 mm. long at 28-mm. centres, through which screws can pass. Centre of slot enlarged to take shafting.

Gearing. Spur gears in seven sizes from 16-96 teeth. Bevel gears, 1:1 and 3:1 ratio. Worm and wheel: 1:2 ratio. Racks, 35 teeth. Internal spur gears, 64 teeth.

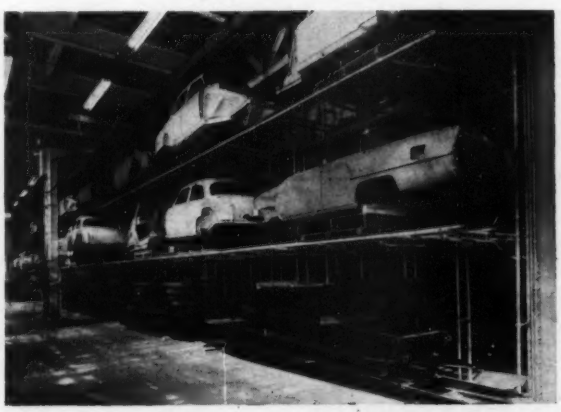
Other parts include circular pressings for forming pulleys and flanged wheels, chain and sprockets, ratchet wheel and pawl, helical spring, hooks, eye-ended tie-wires, brass bushes, spacers, collars, etc.

Cabinets for Electronic Units; Instrument and Switchboard Cubicles

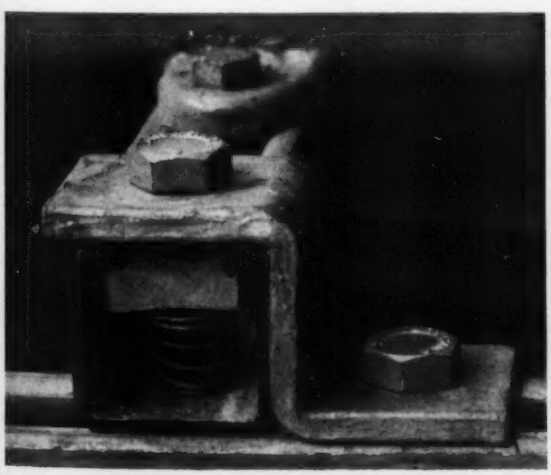
DORMAN & SMITH LTD. (CUBICON)—Selection of standard assemblies for build-it-yourself cubicle switchboards supplied to order. Basic unit comprises bolted-together frame-



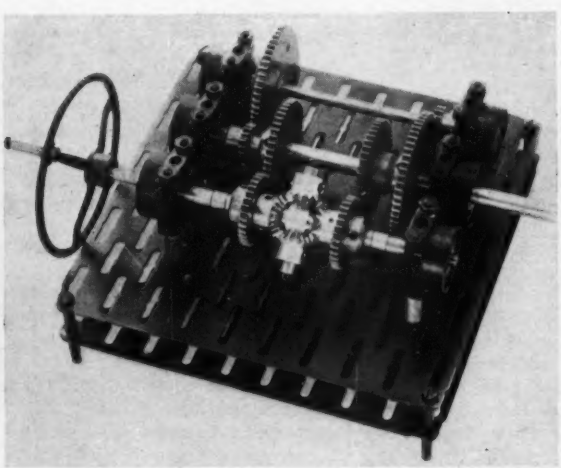
Basic Lektrokit chassis for experimental electronics set-ups.



Assembly line structure built from steel tubing and Kee Klamps.



Unistrut steel channel (actual size 1⅝ × 1⅝ in., 12 s.w.g.), self-locating nut assembly and Z-support.



Typical machine element assembly in Weyco Fac, with which highly complex working models can be constructed.

TABLE 1. Principal ranges of slotted angle systems

Type	Section Dimensions	Material and Finish	Remarks
Acrow-angle (Acrow (Engineers), Ltd.)			
Type A3	1⅜ × 1⅜ in. × 14 s.w.g.	Steel, stove-enamelled grey.	Accessories include panels 36 × 6½ × 1 in., slotted on underside for easy fixing.
Type A2	2⅜ × 1⅜ in. × 14 s.w.g.		
Type A1	3⅜ × 1⅜ in. × 14 s.w.g.		
Chevron (Chevron Structural Units Ltd.)			
Cadet	1½ × 1½ in. × 16 s.w.g.	Cold-rolled steel, granodised and stove-enamelled grey, or with self-finish or galvanised. Standard grade also in aluminium alloy, self-finish.	Right-angle slots designed so that angle may be cut and bolted anywhere. At optimum positions, slots align to take five bolts for maximum rigidity and strength. Accessories include flat strip for curved formation or built-up beam sections; conveyor rollers.
Standard	2 × 2 in. × 14 s.w.g. (steel)		
	2 × 2 in. × 12 s.w.g. (light alloy)		
Super	3 × 2 in. × 12 s.w.g.		
Dexion (Dexion Ltd.)			
Type 112	1⅛ × ¾ × 0·048 in. (steel or light alloy)	Cold-rolled steel, phosphated and stove-enamelled grey. Or aluminium alloy, self-finish.	Round holes for positive location with bolts fully in bearing. Transverse slots for local strengthening and joining short lengths. Accessories include punched steel strap for bracing; conveyor rollers (15 in. or 18 in. wide); Speedframe studs for quick assembly.
Type 140	1⅜ × 1⅜ × 0·07 in. (steel)		
Type 225	2¼ × 1¼ × 0·08 in. (steel)		
	2¼ × 1¼ × 0·092 in. (light alloy)		
Type 300	3 × 1½ × 0·1 in. (steel)		
	3 × 1½ × 0·104 in. (light alloy)		
Grid	Units of 9 in. × 6 ft. or 4 ft. 6 in. × 16 s.w.g.	Phosphated and stove-enamelled grey.	Suitable for floors, ramps, catwalks, stair treads and shelving.
Fabron (H. J. Baldwin & Co. Ltd.)			
Type 300	1½ × 1½ in. × 14 s.w.g.	Cold-rolled steel, stove-enamelled grey, or to order, or zinc-metallised for outdoor use.	Pierced with ¼-in. dia. holes spaced to give rigid joints at 30, 60 and 90 deg. angles. Up to eight bolt fixings possible. Accessories include butt straps; plastics feet; partition clips.
Type 375	2½ × 1½ in. × 14 s.w.g.		
Type 540	2½ × 2½ in. × 12 s.w.g.		
Flowstrut (Fisher & Ludlow Ltd.)			
Junior	1½ × 1½ in. × 14 s.w.g.	Cold-rolled steel, phosphated and stove enamelled grey.	Pierced with 40 slots per linear foot. Accessories include patented Flowclip for rapid assembly of shelves.
Cadet	2½ × 1½ in. × 14 s.w.g.		
Standard	3 × 1½ in. × 14 s.w.g.		
Handy Angle (Handy Angle Ltd.)			
	1½ × 1½ in. × 14 s.w.g.	Steel, rust-proofed and stove-enamelled satin bronze.	Accessories include 8-in. joining strips; plastics feet.
	2½ × 1½ in. × 14 s.w.g.		
	3 × 1½ in. × 12 s.w.g.		
Ly-Tangle (Ardor Insulation Co. Ltd.)			
	2 × 1 in. × 16 s.w.g.	Aluminium alloy extrusion, natural finish.	Special quick assembly claimed.
Nat-angle (National Galvanisers Ltd.)			
Type No. 7	1⅜ × 1⅜ × 0·07 in.		Slot pattern facilitates construction at any angle.
Type No. 8	2¼ × 1¼ × 0·08 in.		
Type No. 10	3 × 1½ × 0·10 in.		
Owen-angle (Rubery, Owen & Co. Ltd.)			
OA/S	1½ × 1½ in. × 14 s.w.g.	Cold-rolled steel, rust-protected and stove-enamelled French grey.	Bolt holes at ¾-in. intervals on all sizes gives adaptability. Provided material is cut across centre of a hole, all other holes will align. Will mate with other forms of slotted angle.
OA/M	2½ × 1½ in. × 14 s.w.g.		
OA/L	3 × 1½ in. × 12 s.w.g.		
Roften (Williams & Williams Ltd.)			
	1½ × 1½ in. × 14 s.w.g.	Steel, spray-painted and stoved in hard silver-grey finish.	12-ft. lengths can be cut to 2 ft., 3 ft., 4 ft. and 6 ft. without waste. Will mate with other forms of slotted angle. Rigid construction at any angle.
	2½ × 1½ in. × 14 s.w.g.		
	3 × 1½ in. × 14 s.w.g.		
	3 × 1½ in. × 12 s.w.g.		
Slangle (Sommerfelds Ltd.)			
	1½ × 1½ × 0·063 in.	Steel, phosphated and stove-enamelled steel grey.	Diagonal slots allow joints to be made at any angle.
	2½ × 1½ in. × 14 s.w.g.		
	3 × 1½ in. × 14 s.w.g.		

NOTE: Most of the slotted angle construction kits referred to above also include such accessories as hinges, castors, speedy cutters, cleats and gusset plates, etc.

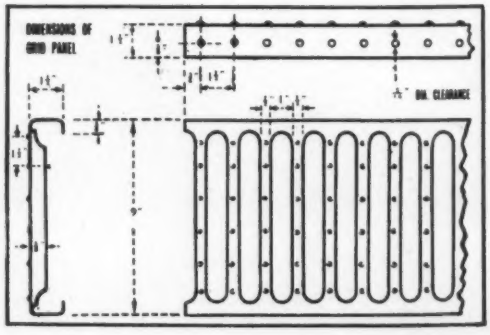
work 2 ft. 6 in. wide, 2 ft. deep, 7 ft. 1 in. high. Switches, etc., mounted on standard slotted plates which form front panels of cubicle.

Material. Sheet steel, stove-enamelled hammer grey finish.

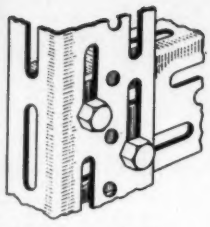
HALLAM, SLEIGH & CHESTON LTD. (WIDNEY DORLEC)—Metal cabinet and rack construction for wide variety of electronic, electrical and hospital units, all shapes and sizes, to order. Cabinets built by first constructing rigid framework of Widney Dorlec corners and extrusions, then fitting doors, panels and equipment as desired.

Materials. Aluminium alloy corner castings and extrusions in three sizes. (Also miniature gauge in mild steel, designed for assembly by spot welding.)

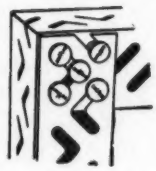
Parts. **Small** gauge corners and extrusions (12-ft lengths) for small consoles and average cabinets, outside radius $\frac{3}{16}$ in. **Standard** gauge corners and extrusions (12-ft. lengths) for control desks, consoles and large cabinets; outside radius $1\frac{3}{16}$ in.; very wide range of parts. **Heavy** gauge, for



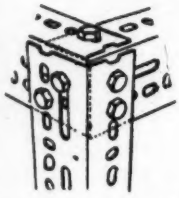
Dexion multi-purpose grid panel, the latest addition to this company's range of quick-assembly materials.



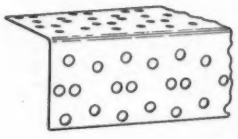
Type A.1 Acrow-Angle.



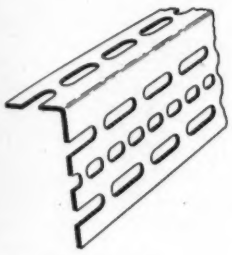
Chevron slots align at each inch.



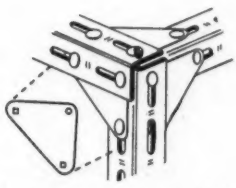
A rigid corner in 225 Dexion.



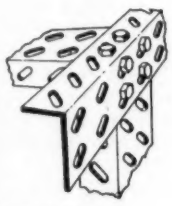
Fabron 300.



Flowstrut Standard.

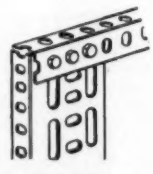


Rigid corner in Handy Angle.

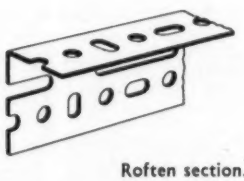


Ly-Tangle joint.

Built-up section in Nat-Angle.



Owen-angle OA/S joined to OA/L section.



Roften section.

Angle joint in Slangle.

really heavy equipment, uses standard gauge components reinforced by steel support brackets.

Features. The Quick-fit interlocking system on the main frame sections comprises an internal flange slotted to accommodate the head of a standard bolt ($\frac{1}{4}$ in. B.S.F. or U.N.F. for small gauge and $\frac{5}{16}$ in. B.S.F. or U.N.F. for standard gauge). Corresponding corner fittings have mating legs drilled to accept bolt. The internal slot in the main frame extrusion serves also for securing internal equipment to framework.

Accessories. Pre-drilled racking strips and cross rails, gusset plates, handles and fasteners, louvres, hinges, etc.

ALFRED IMHOF LTD. (IMLOK)—Metal case and rack construction for wide variety of electronic units, all shapes and sizes, to customers' requirements.

Material. Aluminium alloy.

Parts. Die-cast corner connectors, external and internal, designed to mate with extruded frame members (supplied in 12-ft. lengths), to which they are secured with spring clips, screws or metal adhesives. Varied selection of castings and extrusions for making up both rectangular and slope-fronted cases. Side, top, base and back panels are retained in grooves in the extrusions. Front panels are secured by panel screws to rebated edges of extrusions.

Accessories. Cutting jigs for easy mitring of extrusions, case locks and catches, door pulls, hinges, rubber feet, castors, lifting eye, gusset plates, tapped strip, ventilation ring, etc.

NEW WESTERN (ENGINEERING) LTD. (LOCKMET AND LOCKPLAST)—Standardised interchangeable parts for instrument cubicle construction and control room assemblies. Also supplied as complete cubicles.

Lockmet Extendable System

Materials. $\frac{1}{8}$-in. mild steel plate panels, finished black or any colour in B.S. range.

Parts. Angle section verticals and plinths, $1\frac{1}{2} \times 1\frac{1}{2} \times \frac{3}{16}$ in. Side units, entry units and front units 5 ft. 9 in. high and in width 18, 24, 30, 36 or 45 in. Top cover units from 18 × 18 in. to 36 × 36 in. by 6-in. increments in either dimension, then 45 × 18 in. to 45 × 45 in. by 6-in. and 9-in. increments. Fish plates to mate with panel widths joining top cover to vertical panels. Entry units available with hinged or lift-off door. Front units can be used free-standing with wall ties and easel support.

Lockplast System

Similar in principle to Lockmet, but with plastics panels supported on light alloy framework. Satin finish in ivory, black, white or dark green. Panel units 8 ft. × 24 in., 36 in., or 48 in.; or 7 ft. × 24 in., 34 in., 36 in. or 48 in.

"Bread Board" Kits for Experimental Electronics

ALL-POWER TRANSFORMERS LTD. (LEKTROKIT)—Prefabricated components for constructing experimental electronics set-ups, pre-production models and even small-quantity production. Comprises chassis plates pierced to take components, chassis rails for mounting the chassis, side plates, front panels and cover.

Materials. Chassis plates and rails, 18 s.w.g. half-hard aluminium alloy. Side plates and covers, 20 s.w.g. mild steel, anti-rust treated and stove-enamelled grey. Front panels, 16 s.w.g. half-hard aluminium alloy.

Parts. Chassis rails $16\frac{1}{8}$ in. long, chassis plates, three types, overall dimensions $4\frac{1}{4} \times 4$ in.

Dimensions. **Type 1**—plain perforated $\frac{1}{8}$ in. dia. holes pitched at $\frac{7}{16} \times \frac{1}{4}$ in., alternate rows staggered. For mounting small components and wiring, tagstrips, etc. **Type 2**—as type 1, with the addition of six identical hole groups,

for mounting valve-holders (B7G, B8A, or B9A). **Type 3** as type 1, with the addition of two 1¼ in. dia. holes offset from centre line, for mounting valve-holders (International Octal, Loctal, UX4, UX5, British 4-pin and 5-pin) and leaving a maximum of clear chassis area for mounting small components.

Side plates, square or triangular, 5 × 5 in., pierced for attachment to chassis rails and covers, etc. Front panels and covers, for enclosing chassis for permanent use, forming cabinet 5¼ in. high by 17 in. wide by 5 in. deep. Rack brackets, aluminium alloy extrusions, 1 × 1 in., for bolting to side plates for standard 19-in. rack mounting. Tagstrip, 5⅞ in. long, moulded in 24-way sections.

Heater Cableform—preformed wiring assembly of tinned copper wire, sheathed p.v.c. for use with type 2 chassis plate.

Other accessories include p.t.f.e. lead-through insulators, nylon feed-through bushes, relay mounting plates, brackets, spacers, rubber feet, spring clips, hinges, latch assembly.

SHANDON SCIENTIFIC CO. LTD. (RAPIKON)—Standard kits of slotted plates and girders, and punched holder plates, together with rack.

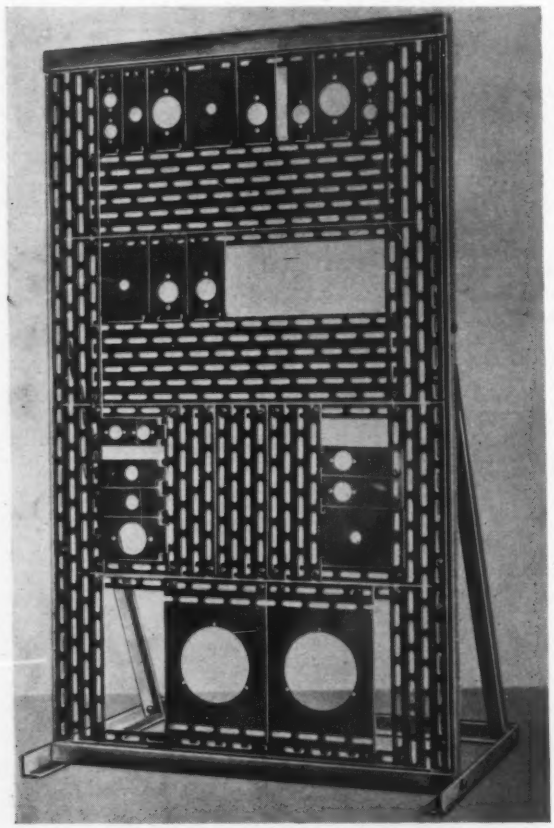
Material. Mild steel, cadmium plated.

Dimensions. Rack for mounting chassis, tapped 4BA, 25⅞ × 15½ in., with base and supporting struts.

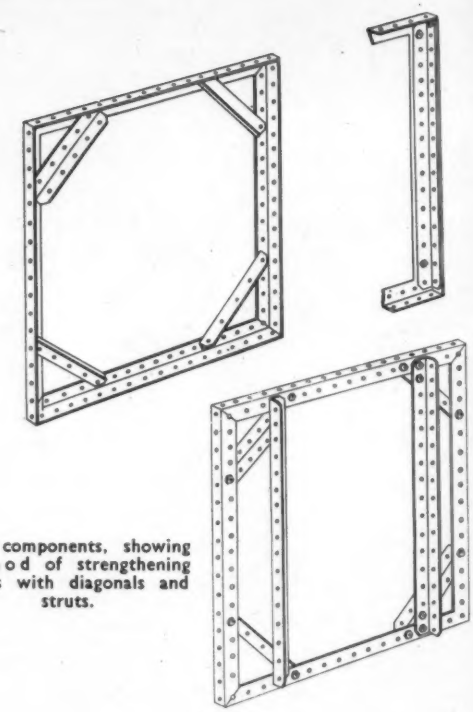
Slotted girders 12 × ½ × ½ in.

Slotted plates, 20 s.w.g., 6 × 1 in., 6 × 2 in., 12 × 3 in., 9 × 2 in.

Holderplates, 20 s.w.g., pierced for Belling Lee coaxial sockets, B7G valve holders, B9G valveholders, rotary switches, potentiometers, toggle switches, fuses, pilot lights,



Experimental electronics rack constructed of Rapikon units.



Basix components, showing method of strengthening frames with diagonals and struts.

International Octal bases, 2-in. meter, 2½ in. meter. One aluminium alloy plate, 6 × 12 in., for drilling by user, and pronged aluminium alloy plates, 3⅛ × 2 in., for drilling by user.

Special-purpose Kits

MULTIFORM STRUCTURES LTD IN ASSOCIATION WITH AERO CONTROLS LTD. (BASIX)—Standard constructional kits specially designed for making aircraft ground-servicing and other structures. System of perforated frames, struts and diagonals.

Materials. Main members in aluminium alloy. *Dimensions.* Basic section of main members is extruded angle, 1¼ × 1¼ × $\frac{1}{16}$ in.

	Frames	*Struts*	*Diagonals*
Large	32 × 42 in.	41·25 in., 21 hole	49·66 in.
Standard	32 × 34 in.	33·25 in., 17 hole	43·68 in.
Three-quarter	32 × 26 in.	25·25 in., 13 ,,	38·45 in.
One-half	32 × 18 in.	17·25 in., 9 ,,	34·36 in.
		12·25 in., 5 ,,	23·88 in.
		7·25 in., 4 ,,	12·56 in.
		3·25 in., 2 ,,	
Pitch of holes	2 in.	2 in.	Standard, 9-hole and 5-hole diagonals drilled at 2·828 in. pitch. Large, three-quarter and one-half frame diagonals drilled only at ends and centre of each flange.

Fittings. Combined wheel and jack units, gusset and angle plates, 45 deg. stairway assemblies.

UNUSUAL SPRINGS FOR SPECIAL PURPOSES

THE use of conventional springs for mechanical purposes is sometimes limited by the force exerted, varying according to the degree of extension. New principles of design and manufacturing technique now enable the designer to utilise spring power for many applications where conventional springs would be unsuitable.

As a constant force extension spring, the element produced by Tensator Ltd. is a length of flat spring material, each portion of which is preset to the same curvature in such a way that it can be completely straightened without deformation. It will be seen from Fig. 2 that when mounted on a freely rotatable spindle and extended from the outer end, force P results, having a line of action through Z. When uncoiled, the spring develops its resisting force in zone X, where the straightening action is taking effect. The completely straightened material, L, stores the energy thus converted, but adds nothing further to the resultant force. Therefore, regardless of the length of extension, zone X remains virtually the same in its length and configuration, and force P remains unchanged.

The spring can be converted into a simple mechanical motor by winding the free end on to a drum of larger diameter than the bush for spring storage. Under such conditions the strip transfers from the larger drum to the smaller, thus producing an output torque at the shaft of the larger drum. A much more powerful type spring motor may be constructed by backbending or reverse winding it on to a torque output bushing. The torque results from the retractive force at the periphery of the storage bushing combined with the additional torque produced by the bending moment required to backbend the straightened section to the shaft of the output bushing.

Increased torque may be obtained by employing a multiple arrangement where a number of these springs are secured to and backbent round a common torque output bushing.

The comparison between a Tensator motor and a power spring is shown in Fig. 1, where the curves were plotted from an actual torque requirement for a cine camera.

Typical applications for these constant force or constant torque springs are in anti-backlash devices, self-winding tapes, clamps and counter balances.

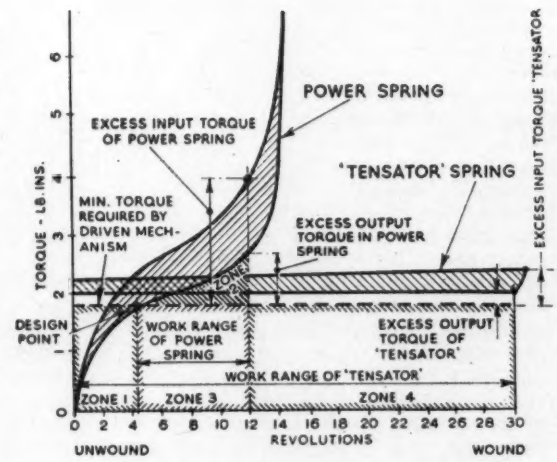


Fig. 1. Torque characteristics of conventional power spring and Tensator spring.

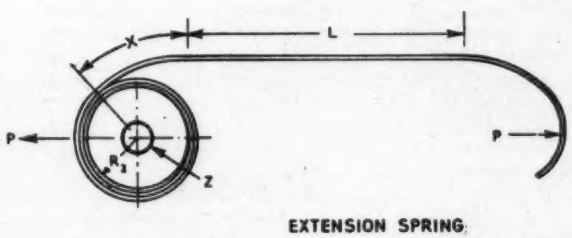


Fig. 2. Elements of Tensator extension spring.

Machined Springs

For instrument and control applications, or any service involving accurate measurement of forces, a wire-wound compression spring has a number of serious disadvantages. It is difficult to obtain a spring with uniform linear spring rate, particularly when high forces are involved, necessitating a small and sometimes fractional number of turns. This so-called "end effect" causes non-linearities in spring rate at low loads. In addition, the lateral stability of most conventionally wound springs is not adequate for precision apparatus, and some additional guidance should be provided to confine the deflection of the spring under load into one axis. Because accurate physical dimensions cannot be maintained in a winding process, suitable adjustments must be provided to compensate for variations in the free length and other physical dimensions of the spring.

To overcome these disadvantages, a series of precision springs identified as Herringbone and Gimbal have been developed by Consolidated Controls Corporation of the U.S.A. for precision instrument and control applications. These springs are machined from solid or tubular stock, heat treated and precisely ground to offer perfectly square ends, tight control of physical dimensions and exact matching of a specified spring rate.

The double helix construction eliminates completely any twist or turning moment between the end faces, thereby avoiding movements which introduce friction. The effective length of the end turn does not change with loads; thus, spring rate is constant from zero load up, even though high loads and fractional turns are employed. The tendency to tilt is eliminated because of the symmetric application of the force output at diametrically opposite points. This, combined with an excellent lateral stiffness, permits the spring to be used as a frictionless bearing in instruments or other applications where additional guidance and bearings would normally introduce undesirable friction.

INVESTMENT CAST COBALT BASE ALLOYS

by M. RIDDIHOUGH, M.Met., A.R.I.C., F.I.M. *

IN its early days, investment casting was used to produce single pieces of statuary in expensive alloys, and its adoption for dental, surgical and jewellery applications during the present century has led to quantity production, though still in expensive metals. However, it was the development of the casting of gas turbine blades in large quantities that brought the process into the engineering field to such an extent that the cheapest metals are now handled economically when circumstances warrant.

HIGH-TEMPERATURE ALLOYS — The process was developed using the cobalt base metals for high-temperature use; in the last few years X-40 has come to the fore and it is now the only cobalt base alloy used to a large extent. Besides good high-temperature properties and resistance to thermal shock, it has excellent casting qualities and is often used for the production of castings which are difficult to produce in other types of high-temperature alloy.

The specification is a relatively wide one which can be held without difficulty in practice with either H.F. or arc melting in the investment foundry. Ingot for arc melting is usually of lower carbon to allow for a little pick-up during re-cycling and the only other element which may vary is the iron content if there is contamination due to shot blasting. Provided the metal is not overheated above 1,600 deg. C., it does not become dirty in melting and it can be re-cycled if adequate control is kept on carbon and general analysis.

A considerable improvement in yield strength is given by ageing, and this remains effective at temperatures higher than that used for ageing. A useful point is that ageing gives more uniform ductility at high temperature and even improves the ductility at 950 deg. C.

Investigations of stress rupture performance by Bristol, de Havilland (see table) and Napier have shown a good level of agreement. The limiting fatigue stress at temperature indicates that vacuum melting or casting does not improve the fatigue properties at high temperature.

The crystal size obtained in a given casting depends on the pouring temperature of the metal and the temperature of the mould, but there is a wide variation in method of entry of molten metal into each cavity and there is probably a wide variation in individual metal temperatures, even although the metal was poured at the one temperature.

As an illustration of this, tests were made by one engine company by pouring a series of moulds at five mould temperatures and four different pouring temperatures, i.e. a total of twenty melts. Investigations included analysis, stress rupture tests, elongation, grain size counts and determination of carbide density.

No relationship is apparent between the stress rupture, elongation and grain size with the metal or mould temperature. However, a relationship is evident between the carbide density and the mould temperature.

The author's experience of general foundry practice with cobalt-base alloys is that a controlled uniform grain size and carbide density throughout the casting is conducive to better corrosion resistance and thermal shock resistance. Dr. N. Grant[1] claims a close correlation between grain size and rupture life.

ABRASION-RESISTANT ALLOYS — In many instances abrasion is accelerated by corrosion and heat. The high carbon and high tungsten composition contains most carbide in the micro-structure, and in general has the greatest wear resistance. Naturally, the greater hardness is accompanied by less ductility and, contrary to steel, the tensile strength also diminishes. This means that, while the softer grades have very good strength of the order of 55 t.s.i. as cast, the harder grades must be supported if subject to heavy load. For instance, extrusion dies of cast cobalt alloy are supported in tool steel bolster hardened to 90-100 t.s.i.

The impact strength at room temperature is adequate and the hard-grade alloy is still less brittle than good quality cast iron. A grade can usually be chosen that is equivalent in corrosion resistance to stainless steel.

Wear resistance is not a property which can be easily assessed, but as the cobalt alloys are resistant to all three factors which bring about wear (i.e., heat, corrosion and indentation), they are vulnerable where two or more of these conditions are found. This compares with structural metals such as stainless steel and cast iron, which are used for simple corrosion or abrasion resistance.

All the above data apply to the alloys in the "as cast" condition. No subsequent heat treatment is carried out, although prolonged heating at 800-1,000 deg. C. causes age hardening to the extent of up to 10 per cent of the original hardness. The alloys are not softened by an annealing treatment or heating to any temperature below the melting point, and it has not been found that stress-relieving treatment is normally necessary for investment castings.

1. "Influences of Metal Structure on Properties of Investment Castings". By Dr. Nicholas J. Grant. *Precision Metal Moulding*, September, 1954, pp. 122-6.

* Doloro Stellite Ltd. This is an abridged version of a paper presented at the first annual conference of the British Investment Casters Technical Association.

Stress rupture v. temperature results with X-40 test bars.

Load (t.s.i.) to produce rupture in	Bristol Aero Engines Ltd.				De Havilland Engine Co. Ltd.				
	Temp. of test, °C.								
	700	800	900	950	700	750	800	850	900
30 hr.	—	—	—	—	24–26	18–20	13–16	10–13	8–10
100 hr.	21·5	13·6	7·5	6·5	19–24	16–19	11–14	9–12	7–9
300 hr.	19·4	11·8	6·3	5·0	18–22	14–17	10–13	8–10·5	6–8
500 hr.	18·4	11·0	5·9	4·2	—	—	—	—	—
750 hr.	17·5	10·1	5·3	3·8	—	—	—	—	—
1,030 hr.	17·0	9·7	5·0	3·2	—	—	—	—	—

GLASS-FLAKE PAPER FOR DIELECTRIC USE

FROM OUR OWN CORRESPONDENT

THE development of a new electrical insulating material in the form of glass flake was described at the recent meeting of the American Institute of Electrical Engineers. Developed by Owens-Corning Fiberglas Corp., the material is said to have characteristics previously not obtained with fibrous glass. The flake is not used solely as a reinforcing or supporting base for dielectric materials, but, because of the configuration of the flake when made in the form of insulating paper, it has been possible to produce a network of platelets similar to that displayed in mica paper or sheets.

This material is produced by drawing molten glass at high speeds into an extremely thin sheet, which is subsequently broken into small flakes.

The glass flake products are believed to have distinct advantages as dielectric materials. Hot-spot temperatures, for example, an important factor in the design of insulation for power equipment, can be readily dispersed by the use of glass-flake insulations because of the excellent thermal conductivity of glass. Glass flakes have been successfully incorporated in a resin for the moulding of stand-off insulators; the voltage stress endurance was found to be superior to that shown by comparable insulators reinforced with fibrous glass.

Phenolic resin laminates with glass-flake paper as a reinforcement have shown improved properties compared with other laminates. These laminates were made with a standard electrical-grade phenolic resin and paper composed of 85 per cent flake and 15 per cent glassine pulp with a 50 per cent resin pick-up.

Increasing Titanium's Acid Resistance

A discovery that greatly improves the corrosion resistance of titanium has been announced by the Union Carbide Metals Co. Research shows that the addition of as little as 0·1 per cent palladium to titanium makes a new alloy which is resistant to boiling solutions of reducing acids (such as hydrochloric and sulphuric), yet which retains titanium's inherent resistance to oxidising acids. Equipment fabricated from the new alloy can now be used with both reducing and oxidising acids, thus greatly increasing the flexibility of the equipment and extending its life.

Conventional titanium alloys have not always been serviceable after use in a reducing atmosphere. In a boiling 5 per cent solution of hydrochloric acid, for example, titanium dissolves at a rate of more than 1 in. per year. However, through the addition of 0·1 per cent palladium (a noble metal of the platinum group), corrosion attack by the same solution is now reduced to less than 0·01 in. per year. It has also been established that titanium's corrosion resistance can also be improved by small additions of most of the other noble metals—platinum, rhenium, ruthenium, indium, osmium, rhodium and gold.

Tests show that mechanical properties of the titanium-palladium alloy are identical with unalloyed titanium. Additions of up to 0·2 per cent palladium have shown no effect on tensile strength or ductility. The new alloy can be cold- or hot-worked without difficulty.

High-temperature Lubricants

Lubricants operable in the 370-540 deg. C. temperature range are promised by the development of meta-polyphenyl ethers by Monsanto Chemical Co. A typical meta-ether has a liquid range of 2-540 deg. C. a calculated life of over fifty hours at 480 deg. C., a 100 deg. C. viscosity of 12·72 c/s, and a viscosity-temperature slope (American Society for Testing Materials) of 0·85 from 25-370 deg. C.

Meta-ethers have good lubricity and hydrolytic, oxidative and radiation stability. They are reported to be as stable at about 450 deg. C. as silicones at 390 deg. C., hydrocarbons at 350 deg. C. and the esters at 280 deg. C.

Rebonded Fused Silica

Previously available only as boules or machined shapes from boules, fused silica (quartz or silica glass) can now be produced in aggregate cast or slip cast form. Developed by Glasrock Corp., the material is made from 99·9 per cent pure silica sand, which is melted by a special process to obtain crude lumps of fused silica. These lumps are then crushed and ground to produce an aggregate.

Rebonded material can be used at temperatures up to about 1,100 deg. C., and has an extremely low coefficient of thermal expansion, providing excellent thermal shock resistance. Thermal conductivity is about 6 B.t.u./hr./sq. ft./°F./in. at 1,000 deg. F. Slip cast density is about 1·8-2·0 gm./cu. cm. porosity is 12-18 per cent, and the material has a Moh's hardness of 6-7.

Rebonded material is weaker than solid fused silica glass. Parts normally supplied are said to have a modulus of rupture ranging from 300-4,000 p.s.i., depending on fabrication conditions.

Chemical resistance and electrical properties are apparently very similar to those of silica glass, except for an allowance for porosity. In the case of chemical resistance, porosity provides greater exposed surface area. Potential applications include permanent moulds for metal casting, furnace hearths and furniture and crucibles.

New Plastic Film for Outdoor Use

Semi-works production of a new transparent polyvinyl fluoride film with excellent weatherability, chemical resistance and mechanical strength has been announced by E. I. du Pont de Nemours & Co. Inc.

Designated Type R film, specimens have not embrittled or discoloured after ten years' exposure in Florida. Supported film is expected to have even longer outdoor life. The film is said to have excellent resistance to a wide range of chemicals, including 10 per cent sulphuric acid, 10 per cent sodium hydroxide and carbon tetrachloride.

The film can be used over a temperature range of −100 to 120 deg. C. It is non-plasticised, and said to have high tensile strength and flex life. Dielectric constant is 7·5 (60 c/s, 20 deg. C.); dielectric strength is said to be high.

Available in satin or glossy finish, and in widths of 42-50 in., the material is initially priced at $5/lb.; area factor is 140 sq. ft./lb./mil. Potential applications include agricultural glazing, packaging, industrial and decorative tapes and signs, and as a surfacing material.

New Books

Electronic Engineer's Reference Book. *Edited by L. E. C. Hughes.* (*Heywood, 84s.*)

THE second edition of this work contains a considerable amount of new material including that on non-destructive testing, radiation detection, digital computer applications and simulators.

The main chapter headings cover the fields of Fundamentals, Radiations, Electrics, Valves, Materials, Vibrations, Computing Automatics and Miscellaneous. Some of these are at first misleading, for under "Valves" we find valve voltmeters, counters, C.R.O.s and transistor circuitry, in addition to valve data, base connections, etc. However, the contents are well laid out and the use of decimal sequence for numbering paragraphs enables rapid location of a particular subject in most instances, though transformers seem to be an exception in coming to rest in the largest section, i.e., Automatics. This subject covers 269 pages and includes machine control systems, office facilities, simulation and telephone exchanges among many others.

This book, containing no less than 1,580 pages and 800 illustrations, includes a wealth of bibliography and will be invaluable to the electronic specialist as well as to the qualified engineer whose contact with electronics is increasing.

S.C.

Technology of Printed Circuits. *By Paul Eisler.* (*Heywood, 60s.*)

This publication is written in an interesting manner and covers technology from the confused start, the popular accepted methods now considered to be the best, design, manufacture and bibliography. From the design and materials point of view, this book is most authoritative. The "Confused Start of a New Technology" does, in fact, appear confused, but following the history which is contained within twenty pages, the book gives an illustrative account of up-to-date technical developments, together with design data, graphs and perimeters, which are explained in a most readily understandable way. The book is well illustrated with some 150 figures, and the necessary mathematics are simple to follow. Four pages are devoted to "materials bibliography" which will be of particular interest to readers.

Engineers generally will be better informed after reading this work, which will also serve as a useful reference.

C.J.F.

Dictionary of Physics. *Compiled and edited by H. J. Gray.* (*Longmans, 84s.*)

The engineering designer is today more closely linked to an aspect of physics than at any previous time, and while an intimate knowledge of a particular branch is not always required, it is desirable to understand the vocabulary employed. This dictionary is the second edition and adequately fulfils this need. Alphabetically arranged, it covers all branches of physics and contains many line drawings amplifying the explanations. A preface contains useful notes relating to nuclear physics, while tables of elements, the periodic table, fundamental physical constants, logarithmic and trigonometric tables are included at the end of the book.

Glass Engineering Handbook. *By E. B. Shand.* (*McGraw Hill, 77s. 6d.*)

The author states in his preface that this is a handbook on composition, manufacture, properties and applications of glass as an engineering material.

The first section contains a comprehensive survey of glass properties, together with an extensive list of references and graphs. Part of the section deals with recent information on high-energy radiation effects and its associated problems. The second section deals in a very much abridged manner, with the melting and forming of glass, and concludes with American manufacturers' tolerances for sheet, plate and container glass.

The third section is probably the most important for the engineer, containing, as it does, numerous tables designed to be of assistance to anyone contemplating the use of glass for sound and heat insulation, industrial pipelines, gauge glasses illuminations, etc. The fourth section, written by J. A. Grant of Owens-Corn Fiberglas Corp., devotes 88 pages to all aspects of glass fibre production and application, together with a large number of useful facts and figures.

This book could serve a dual purpose: as a reference for glass technologists and engineers, and as a guide to the many varied applications of the material for people outside the industry.

W.E.N.

Patents for Engineers. *Laurence H. A. Carr and J. C. Wood.* (*Chapman and Hall, 18s.*)

This is a useful book which would have been much more useful if it had been longer and had shown more thoroughness in its treatment of the subject. It will have value as general reading for engineers and others who wish to gain a working idea of the structure of the law and practice concerning patents, but is too discursive and incomplete to be of serious use to the student. Of its seven chapters, one deals with matters other than patents, including trade-marks and copyright, and one is devoted to a discussion of patents of purely historic interest, so that only five chapters, of a total of sixty pages, deal with present patent law and practice. It is perhaps inevitable that in so short a summary there should be occasional over-simplifications, such as the statement that "the owner of a patent may deal with it in the same way as with any other piece of personal property". For the same reason, the subject of foreign patents, which to the engineer engaged in export is of considerable importance, is dismissed in a few hundred words.

A more fundamental criticism is that the authors seem to think that every invention ought to be the subject of a patent. The practical engineer in industry, anxious not to load his costs with a snowball of patent fees, needs guidance toward a patent policy, a set of criteria by which he can decide what to patent and what to leave unpatented. He will not find it in this book.

A.H.B.

Casting in Steel. *Published for British Steel Founders Assoc. by* (*Pitman, 18s.*)

The B.S.F.A., rightly believing that steel castings could with advantage be more widely used, have, during the past ten years, published a series of technical and semi-technical booklets addressed primarily to those who design and buy steel castings. These scripts, long since recognised as being authoritative, have been amalgamated, revised and expanded into a most handsome volume. The information enables the designer to utilise fully flexibility in the design of cast steel components.

LETTER TO THE EDITOR

Standardising "High Tensile"

Sir,

It is part of my professional duty to see large numbers of inquiries for bolts, nuts and allied components. In the bolt industry, 45 t.s.i. and upwards is the usual interpretation of "high tensile". I agree that, as a definition, it is as precise as "mild steel" or "light alloy".

Without detracting from the theme of your article (Editorial, May issue), i.e., clarification of the meaning of a technical description, may I suggest that far more help would be given to manufacturers if not only such imprecise terms as "high tensile" were abandoned, but that the multitude of firms, small and large, who lay down quite precisely their own conditions and descriptions in private specifications, would refrain from doing so. There is a comprehensive series of steel standards, and most other items of common use, in the form of internationally recognised specifications published by the British Standards Institution. Their formulation is by agreement with the interests and users concerned; they should, therefore, be acceptable. Their extended use would be gratefully received by many people.

I. Holman

Chief metallurgist,
L. H. Newton & Co. Ltd.,
Nechells,
Birmingham, 7.

ALKYD MOULDING MATERIALS

Engineering Materials and Design
DATA SHEET No. 18

MECHANICAL PROPERTIES

	Tensile Strength	Flexural Strength	Modulus of Elasticity	Izod Impact Strength	Compressive Strength	Hardness
	p.s.i.	p.s.i.	p.s.i.	ft. lb./in. of notch	p.s.i.	Barcol
General purpose	3,000–4,000	7,000–10,000	$(2{\cdot}2–2{\cdot}7) \times 10^6$	0·30–0·35	16,000–20,000	60–70
General purpose, self-extinguishing	3,000–4,000	7,000–10,000	$(2{\cdot}2–2{\cdot}7) \times 10^6$	0·30–0·35	18,000–21,000	55–65
High impact, flame resistant	6,000–10,000	14,000–17,000	$(2{\cdot}2–2{\cdot}8) \times 10^6$	8–12	20,000–25,000	70–80
General purpose, high flow	3,000–4,000	8,000–10,000	$(1{\cdot}4–1{\cdot}8) \times 10^6$	0·25–0·35	18,000–24,000	60–70
General purpose, self-extinguishing, high flow	3,000–4,000	8,000–10,000	$(1{\cdot}8–2{\cdot}5) \times 10^6$	0·25–0·35	18,000–24,000	60–70
High dielectric grade	3,000–4,000	7,000–10,000	$(2{\cdot}8–3{\cdot}1) \times 10^6$	0·30–0·35	18,000–22,000	60–70

THERMAL PROPERTIES

	Thermal Expansion	Thermal Conductivity	Heat Distortion Temp. (264 p.s.i. fibre stress)
	in./in./°F.	cal./sec./cm.²/°C.	°C.
General purpose	$(1–3) \times 10^{-5}$	$(15–25) \times 10^{-4}$	175–210
General purpose, self-extinguishing	$(1–3) \times 10^{-5}$	$(15–25) \times 10^{-4}$	175–210
High impact, flame resistant	$(1–3) \times 10^{-5}$	$(8–12) \times 10^{-4}$	>210
General purpose, high flow	$(1–3) \times 10^{-5}$	$(15–25) \times 10^{-4}$	175–210
General purpose, self-extinguishing, high flow	$(1–3) \times 10^{-5}$	$(15–25) \times 10^{-4}$	175–210
High dielectric grade	$(1–3) \times 10^{-5}$	$(15–25) \times 10^{-4}$	175–210

ELECTRICAL PROPERTIES

	Power Factor		Dielectric Constant		Electric Strength	Surface Resistivity	Volume Resistivity
	at 60 c/s	at 10^6 c/s	at 60 c/s	at 10^6 c/s			
					volt/mil.	ohm	ohm/cm.
General purpose	0·050–0·060	0·016–0·028	6·0–6·5	4·8–5·0	300–400	$>10^{14}$	$>10^{14}$
General purpose, self-extinguishing	0·035–0·040	0·014–0·015	6·0–6·5	4·2–4·5	300–400	—	—
High impact, flame resistant	0·02–0·03	0·017–0·022	5·2–6·0	4·0–4·5	300–400	—	—
General purpose, high flow	0·035–0·045	0·028–0·035	5·9–6·4	4·8–5·1	300–400	—	—
General purpose, self-extinguishing, high flow	0·035–0·040	0·014–0·017	5·8–6·2	4·4–4·6	300–400	—	—
High dielectric grade	0·017–0·019	0·019–0·021	10·5–12·0	9·5–10·0	300–400	—	—

GENERAL PROPERTIES

	S.G. of Moulded Material	Water Absorption, %*	Chemical Resistance	Hydrocarbons and Alcohol
General purpose	2·18–2·22	0·08–0·10		
General purpose, self-extinguishing	2·16–2·18	0·05–0·08	Withstands weak acids	Not affected
High impact, flame resistant	2·0–2·08	0·10–0·20	Attacked by alkalis	
General purpose, high flow	1·80–1·83	0·39–0·41		
General purpose, self-extinguishing, high flow	2·05–2·15	0·05–0·08		
High dielectric grade	2·52–2·55	0·04–0·06		

* 2 in. dia. × ⅛ in. thick disc immersed for 24 hours.

Data Sheet by Yarsley Research Laboratories Ltd.

Expansion, contraction and lateral movement of pipe work under extreme conditions of temperature and pressure is no problem to the engineer who has been wise enough to contact and consult TEDDINGTON technicians. Teddington Bellows Expansion Joint cylinders are butt-welded from highly finished cold rolled stainless steel sheet. Convolutions are introduced to give the bellows their characteristic flexibility. Nuclear, chemical, marine and gas engineers acknowledge their efficiency and superiority over many older forms of expansion joint. Wherever pipe-work is subjected to vibration or movement in any direction, a Teddington Bellows with a suitable end-fitting will solve the problem.

SEND FOR BROCHURE No. X77

Teddington Bellows are produced in technical collaboration with the Solar Aircraft Co., U.S.A.

TEDDINGTON BELLOWS

EXPANSION JOINTS

TEDDINGTON AIRCRAFT CONTROLS LTD. (*Industrial Bellows Division*)
Ammanford, Carmarthenshire. Tel.: Ammanford 2255

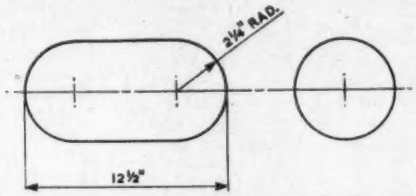
CALCULATING VOLUMES AND SURFACE AREAS OF CYLINDERS AND SPHERES

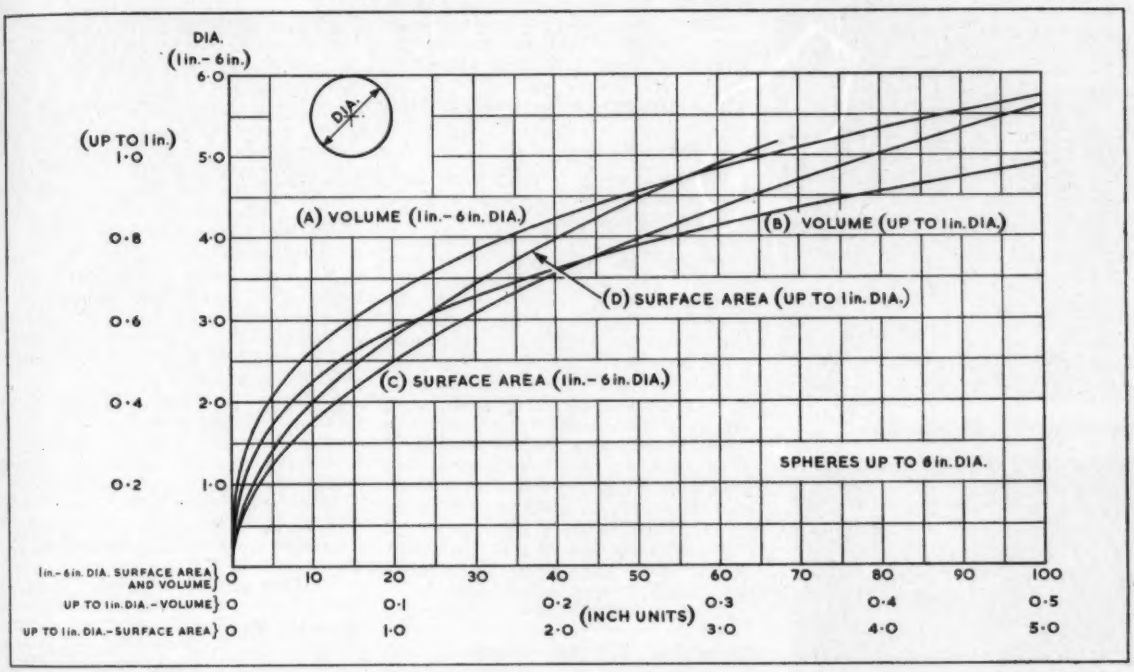
Engineering Materials and Design
DATA SHEET No. 19

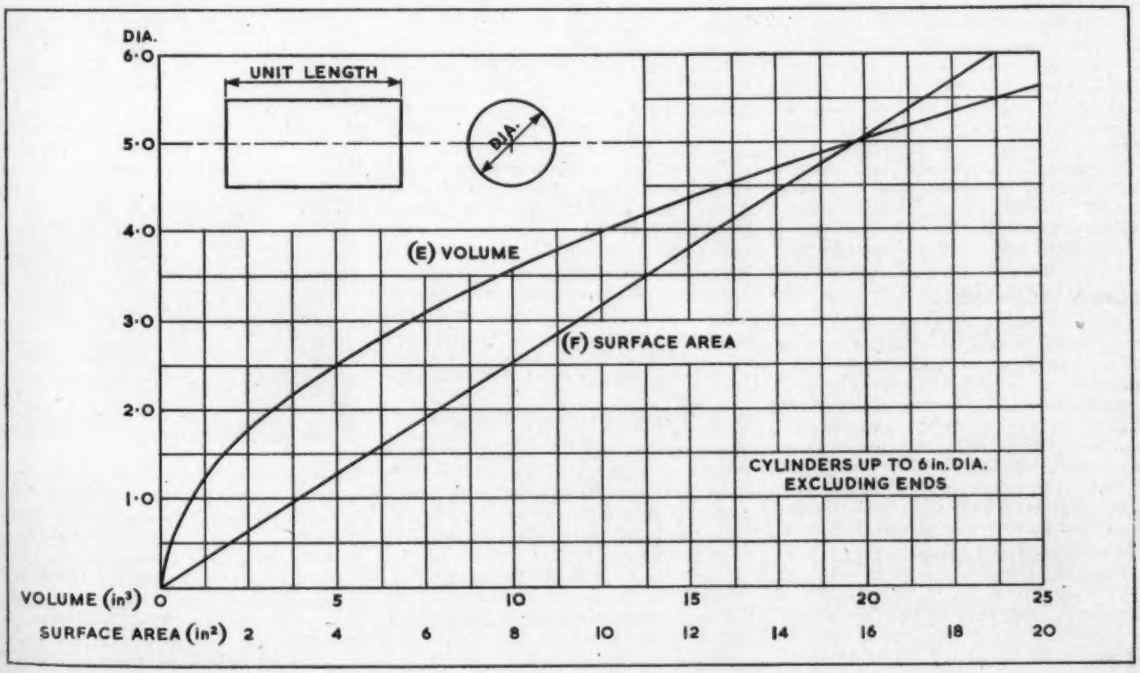
Example

Find the volume of a cylindrical hemi-spherical ended container 12½ in. long and 4½ in. diameter.

Volume of ends from curve A = 47·7 in.³
Volume of cylinder from curve E = 15·9 × cylinder length
= 15·9 × 8
= 127·2
Total volume = 47·7 + 127·2
= 174·9 in.³




DIA.
(1 in. – 6 in.)
(UP TO 1 in.)
DIA.
(A) VOLUME (1 in. – 6 in. DIA.)
(B) VOLUME (UP TO 1 in. DIA.)
(C) SURFACE AREA (1 in. – 6 in. DIA.)
(D) SURFACE AREA (UP TO 1 in. DIA.)
SPHERES UP TO 6 in. DIA.
1 in. – 6 in. DIA. SURFACE AREA AND VOLUME
UP TO 1 in. DIA. – VOLUME
UP TO 1 in. DIA. – SURFACE AREA
(INCH UNITS)



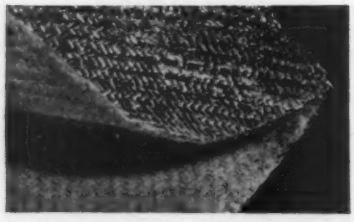
WHAT'S NEW IN MATERIALS & COMPONENTS

High-grade Tool Steel

A new high-grade tool and die steel now being produced in this country is said to be the only one of its kind produced in the form of ground round stock. Considerable savings are claimed for it in the time and cost of machining, as it is ground to within tolerances of −0 to +0·001 in. or even finer if required. Marketed under the name of Crusader NSR, it is an oil-hardening steel and, according to the degree of tempering, its hardness can be varied from 56 to 62 Rockwell C scale. After grinding, the material is dipped in a lanolin base composition and wrapped in a vegetable parchment paper that is completely acid-free. The pieces are then sealed and placed in bitumen bonded paper packets containing vapour-phase inhibitor paper. The steel is available in lengths of 18 in. and diameters ranging from $\frac{1}{16}$ in. to 1 in. It has an analysis of 0·95 per cent carbon, 1·7 per cent manganese, 0·25 per cent chromium and 0·25 per cent vanadium. Geo. Sorby Ltd.

EMD 1079 for further information

Aluminium-faced Asbestos



A further addition to the range of asbestos cloths available is a series of grades having a coating of bright and highly-reflective aluminium. This introduction is expected to find valuable applications for thermal insulation problems, including those concerned with shipbuilding, gas turbine and aircraft manufacture, fire-fighting and other protective clothing uses. Turner Bros. Asbestos Co. Ltd.

EMD 1080 for further information

Porous Polyethylene

A new porous plastics material with many possible uses is being produced in this country from high-density polyethylene of the Ziegler type. The new material, Vyon, has already found applications in air and liquid filtration, air fluidised powder conveying, and as aeration pads and electrolytic diaphragms. It is said to be tough and flexible and also light and easily fabricated. It is machinable and can be welded and drilled. A permeable material of medium pore size, its permeability is said to be uniform and can be controlled in manufacture.

It is claimed to have excellent chemical resistance to a wide range of aqueous solutions. When used in liquid filtration, the advantages claimed are complete freedom from detachable fibres and smooth surface to facilitate mechanical cleaning. In many filtration applications it can be used unsupported.

Vyon is available in stock sheets up to 32 in. square and from 0·03-0·2 in. thickness. Permeability is varied in manufacture to suit each application, the maximum obtainable being some 50 cu. ft./min. of air at 0·25 p.s.i. for a sheet ¼ in. thick. Pritchett & Gold and E.P.S. Co. Ltd.

EMD 1081 for further information

New Refractories

The Purox range of high-purity and recrystallised alumina now includes three new oxide refractories. Thoria is available with a purity of 99.9 per cent ThO_2 in standard and impervious forms. It is said to be serviceable at temperatures up to 2,600 deg. C. and is therefore one of the most refractory materials commercially available. Magnesia, which has a recommended maximum service temperature of 2,400 deg. C., is available in the form of crucibles, tubes, bricks, tiles and small die pressings. The purity of this material varies according to methods of manufacture, but is claimed to be always better than 98 per cent. The third material is zirconia, which is fully stabilised and said to be 97 per cent ZrO_2. Crucibles, tubes and sheaths are available for service temperatures up to 2,500 deg. C. Morgan Refractories Ltd.

EMD 1082 for further information

Corrosion-resistant Finish

Endurion is a new process that is claimed to impart, by immersion, a fine-textured, corrosion-resistant finish to ferrous metals with a considerable lubricity factor. It is a non-toxic chemical after-treatment applied to a base of phosphate coating, and is claimed to give maximum corrosion resistance with minimum dimensional build-up. Parts protected by this process are said to remain serviceable for as much as sixteen times as long as when treated with phosphate, though it can, if required, be easily integrated with existing phosphate operations. Endurion produces no toxic fumes and is said to require no expensive equipment, electric power or special installations. B.B. Chemical Co. Ltd.

EMD 1083 for further information

U. V. Resistant Polystyrene

A special light-resistant grade of polystyrene, Lustrex UVL, has been developed to retain maximum clarity and whiteness over a period of exposure to ultra-violet and other radiations emitted from fluorescent tubes in normal use.

Lustrex UVL has many features that commend it for use in fluorescent lighting equipment. Advantages claimed are that it may be injection moulded into intricate patterns, is light in weight, inexpensive and obtainable as crystal clear, translucent white, or in a variety of transparent or translucent colours. It is said to be particularly useful for the manufacture of diffusers, louvres and shades for fluorescent lighting assemblies. Monsanto Chemicals Ltd.

EMD 1084 for further information

Two New Grades of Kieselguhr

Two new grades of German kieselguhr are now available in the U.K. for filtration applications.

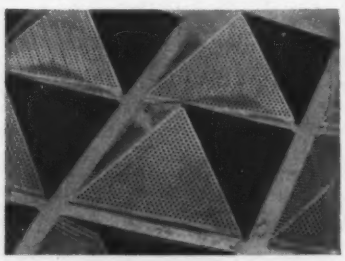
Kieselguhr 80-Special is a very high quality grade with a good white colour and large bulk volume. It is made up of carefully selected and balanced diatoms, all within the size range of 30-90 microns. This ensures full suspension during the complete filtration period. It is claimed to have an excellent flow rate with extended period of cycle and above-average clarification. It is primarily devised for the brewing and other trades requiring a chemically inert kieselguhr which will give a good clarity of filtrate without loss of speed.

Kieselguhr 80-Quick is slightly off-white and is said to give a very fast filtration rate with medium clarification. It is specially recommended for applications where build-up of back pressure is to be delayed and when highly viscous liquids, such as heavy oils or sugar syrup, are involved. Charles H. Windschuegl Ltd.

EMD 1085 for further information

Acoustic Material

The Acoustic Pyramid is an acoustic absorbent unit formed from rigid p.v.c., perforated and filled with mineral wool. The base of each pyramid is 22 in. square, including a ½-in. flange. The depth is 8½ in. When sound reaches the pyramid a large proportion of it is absorbed, and reflection is said to be eliminated. At a frequency of 1,000 c/s the absorption of these panels is said to



reach the very high value of 95 per cent. For all frequencies from 125-2,000 c/s, the absorption exceeds an average of 60 per cent. It is said that the pyramids can be fixed easily and quickly to any firm surface, including sloping ones. A spiral spring fixed inside each panel is attached to a hook on the surface which is to be insulated. Marley Tile Co. Ltd.

EMD 1086 for further information

Silver Minalpha

Minalpha is a copper-nickel-manganese alloy that was developed as an alternative to Manganin. Its main characteristics are a specific resistance of 41·5 $\mu\Omega$-cm and a change of resistance over the temperature range 10-40 deg. C. or less than 150 parts per million, i.e., about 5 p.p.m. per deg. C.

Silver Minalpha is a new product comprising a core of Minalpha sheathed with a silver-tin-manganese alloy. By choosing the correct diameter ratio for the core and the sheath, it is claimed that it is possible to produce a wire in which the two approximately equal and opposite temperature/resistance characteristics largely cancel one another. The composite wire is thus said to have built-in parallel temperature compensation which is fully effective over the temperature range 10-100 deg. C.

The silver-alloy outer surface of the composite wire is said to be more readily solderable than Minalpha and in potentiometers or variable resistors to give a more satisfactory electrical contact. Johnson Matthey & Co. Ltd.

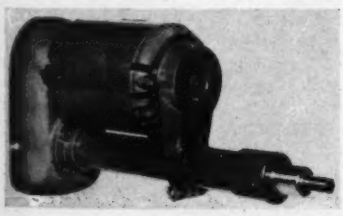
EMD 1087 for further information

P.V.C. on Steel Laminates

A plastics-steel laminate, known as Plasteel, which has been developed by the British Iron and Steel Research Association, is now being manufactured under licence by two firms in this country. The material is a laminate consisting of steel strip or sheet with a bonded face of p.v.c. It is said to combine the strength of steel with the "warm" and attractive finish of p.v.c. in colours ranging from tartan to red, white and blue. Applications include kitchen and office equipment, external and internal building purposes, and automobile trims. Richard Thomas & Baldwins Ltd. and Willmott Taylor Ltd.

EMD 1088 for further information

Electro-mechanical Thrust Units



A standard range of self-contained electro-mechanical thrust units has been put on the market. In various sizes, they are to be offered as alternatives to solenoids and hydraulic, compressed-air and vacuum-operated cylinders. They are claimed to have the advantage that they can be operated directly from standard a.c. electrical supplies, using standard types and switchgear, and the need for special power sources, such as air compressors and hydraulic pumps, etc., is eliminated.

Each unit incorporates an electric motor, totally-enclosed reduction gearing, and a ram which is extended or retracted by means of a screwed shaft and nut arrangement. A special limit switch device is normally fitted to control the stroke, and this can readily be adjusted to give any stroke length within the range of the unit.

Units are available in various sizes, suitable for thrust loads from 0 to 5,000 lb. with maximum stroke lengths to order. They are available for foot, flange or trunnion mounting. Geo. Angus & Co. Ltd.

EMD 1089 for further information

Versatile Castor

A new castor designed originally for the explosives industry, but having other applications, incorporates a 12 × 2 in. soft tread composition wheel secured to a manganese bronze hub housing double tapered roller bearings adequately sealed against the intrusion of nitric acid fumes. The fork and flange are also of manganese bronze and the double tapered roller bearings in the flange are sealed for the same purpose. A vertical direction-locking tommy-bar, when pushed upwards into an extended boss of the main flange housing, converts the castor to a fixed direction wheel bracket; the tommy-bar is spring-loaded and non-rotatable.

The capacity of the castor wheel is 6 cwt., but the castor fitting itself, if housing a metal wheel, has a capacity of 15 cwt. Bearings are grease-packed for life service. Autoset (Production) Ltd.

EMD 1090 for further information

Mineral Insulated Thermocouples

The principle of mineral insulation is now being applied to thermocouple production. The thermocouples consist of two dissimilar thermo-electric conductors, welded together at a point (the hot junction), embedded in highly compressed magnesium oxide insulant and completely encased in a seamless, circular, stainless-steel sheath. The positive conductor is of nickel-chromium alloy and the negative conductor of nickel-aluminium alloy.

They are available in standard overall diameter sizes of 0·122 in. and 0·060 in., but intermediate sizes are also available.

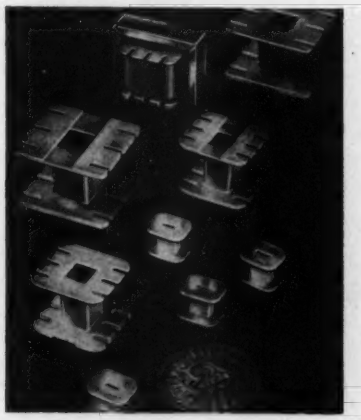
A recent addition to the range has been made possible by drawing on established cable manufacturing techniques. By laying up M.I. stainless-steel-sheathed thermocouples together with stainless-steel strands a multiple flexible thermocouple of small overall diameter and high tensile strength is produced. B.I.C.C. Ltd.

EMD 1091 for further information

Nylon Coil Bobbins

A stock range has now been introduced of nylon coil bobbins produced by the GG Minimoulding process; this is to meet the fast-growing demand of the radio and electronics industry for miniature transformers for printed circuit and similar work. Initial sizes are for square stacks of MEA 187 (RCL 450), MEA 262 (RCL 531) and MEA 218 laminations. The bobbins are designed with universal slots for bringing out leads and a hole flush with the inside of former for the first tap.

The bobbins, being of one-piece construction, are claimed to cut winding and



handling costs and to have excellent dielectric strength. They are produced by a high-speed, single-impression method to give maximum accuracy and uniform quality. George Goodman Ltd.

EMD 1092 for further information

Silvered Mica Capacitors

New silvered mica capacitors have been designed for use over the temperature range of −70 deg. C. to +250 deg. C. and are protected by a dip coating of special silicone rubber. Fired construction is employed, the individual silvered mica plates being bonded into a solid block.

Two standard sizes are manufactured and any capacitance value in the range 5 to 50,000 $\mu\mu$F. can be supplied to a minimum tolerance of $\pm\frac{1}{2}$ per cent or 1 $\mu\mu$F., whichever is the greater. Each size is available rated at 200 or 350 volts peak for temperatures up to 100 deg. C. These ratings are reduced to 100 and 200 volts peak at 250 deg C. Johnson, Matthey & Co. Ltd.

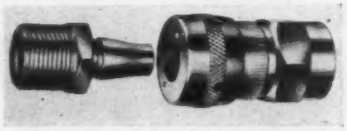
EMD 1093 for further information

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

Quick-acting Coupler

To the range of heavy-duty-type quick-acting couplers available has been added one with an inlet thread of ¾ in. This wide bore is said to be particularly suited to the pneumatic tools used in shipyards and for pneumatic drills and similar



equipment which is power fed through wide-bore hose.

The complete coupler consists of two parts—a check unit which is fitted to the air line or supply from the compressor and an adapter which is fitted to the hose of the tool or equipment. When the adapter is pushed into the check unit it opens the line pressure to the tool, and at the same time snaps into a locked, air-tight connection. The adapter will not disconnect accidentally, yet a twist on the sleeve of the check unit will release the adapter and immediately reseal the air line. When coupled the adapter swivels in the check unit to avoid kinking the hose. The rate of free air flow through the coupler is approximately 100 c.f.m. at 100 p.s.i. inlet pressure. A. Schrader's Son.

EMD 1094 for further information

Small Industrial Pump

A small pump recently introduced is basically a vibrator type of miniature size and is supplied to give the performance required of it by the user. It is adaptable to a wide variety of technical operations in many industries, both as a component built into equipment and in research laboratories. The pump can be supplied in either a metal or plastics cylindrical case, weighing 24 oz. or 30 oz. respectively. The pump is available in a range to give positive or negative pressure in closed or open circuit, suitable for liquids or gases, including corrosive gases, and can be supplied for a.c. voltages from 24 volts upwards. Inlet and outlet connections and mountings can be adapted to requirements. Singleton Bros. (Instruments) Ltd.

EMD 1095 for further information

Castors

A new series of double ball bearing heavy/medium-duty castors is now on the market in the U.K. These castors are said to be of sound design and construction, to have remarkable ease of mobility and to incorporate a swivel race which is easily adjustable. Manufactured with plate fitting and male and female tubular fittings, there are also stationary castors to match both types. A wide variety of wheels, including cast-iron, cast-iron rubber tyred, phenolic resin-bonded and solid rubber are available in 4-in., 5-in., 6-in. and 8-in. sizes. Flexello Castors & Wheels Ltd.

EMD 1096 for further information

Battery Guard

A device known as the Herco battery guard has been designed to maintain the acid level in a lead-acid type battery. It consists of a small flexible plastics container which screws in the top of the battery in place of the conventional plug. The container is first filled with distilled water, inverted and screwed into the battery. A short tube extends downwards to the correct acid level and so long as the opening of the tube is covered with acid no water escapes from the container. As soon as the acid level drops due to evaporation, air is admitted to the container and water released. Gases produced by the battery on charging are released through slots in the threaded portion of the container. Herco W. Hermann & Co. G.m.b.H.

EMD 1097 for further information

High-speed Connections

High-pressure and temperature connections utilising a special sealing system for efficient and high-speed connection of standard pipe sizes and other adaptations are now being produced in this country under U.S. licence. Known as Ruston-Grayloc units, they include a butt welding

type (see illustration), socket welding type and threaded type. Connections up to 30 in. are available for piping, vessels or other requirements. They are claimed to be self-aligning, valuable not only for permanent connections, but can be broken and remade repeatedly using the same sealing member. Other features claimed for the connections are that they cost less and weigh less than corresponding high-pressure flange assemblies and that they cannot be overtightened. They are available in a variety of materials to resist corrosion. Ruston & Hornsby Ltd.

EMD 1098 for further information

New Publications and Technical Literature

Burgess Products Co.: *Micro Switchcraft.* This issue is devoted to microswitch selection.

EMD 1099

Cambridge Instrument Co.: 16-page publication dealing with technical problems associated with gas analysis by the thermal conductivity method.

EMD 1100

Copper Development Assoc.: Booklet devoted to properties of copper and its alloys for electrical work, the manufacturers of copper wire, power, transmission and other types of insulated cables.

EMD 1101

Elcontrol Ltd.: Revised data sheet TR, issue 2, describing their range of standard electronic process timers, cyclic timers and delay switches.

EMD 1102

Elkay Electrical Mfg. Co.: Leaflet dealing with weatherproof nylon cable glands and plastics insulating bushes.

EMD 1103

Harvey Aluminium: Comprehensive brochure on titanium for engineers, metallurgists and designers, describing its production, properties and range of applications.

EMD 1104

I.C.I. Ltd.: *Metals for Nuclear Energy.* Handsome brochure detailing the part played by the Metals Division in the early days of nuclear engineering and the research and development subsequently carried out.

EMD 1105

Machine Tool Trades Assoc.: Attractive colour brochure prepared by the European Committee for Co-operation of the Machine Tool Industries, reviewing how machine tools serve the economy of the world and how their role can be increased.

EMD 1106

Morgan Crucible Co.: Brochure describing use of Tri-Mor castable and mouldable refractories.

EMD 1107

Westinghouse Brake & Signal Co.: Revised catalogues for pneumatic control valves and axle counters for colliery equipment.

EMD 1108

Henry Wiggin & Co.: Booklet describing the properties and uses of various grades of nickel-chromium and nickel-chromium alloys in the Brightray series. Another recent publication of considerable note is the fiftieth edition of *Wiggin Nickel Alloys.*

EMD 1109

Technical Ceramics Ltd.: Leaflet describing vibration strain gauges used for determination and analysis of dynamic strains.

EMD 1110

Zinc Development Assoc.: *Die Casting News.* First of a new series of bulletins illustrating particular advantages of die casting in zinc alloy.

EMD 1111

Steel Sandwich

Spacemetal is a stainless-steel sandwich of low density, high strength and excellent heat resistance. It consists of an inner sheet beaded to form a V-shaped corrugation and is surfaced on both sides with a plain sheet of type 301 stainless steel with a nominal gauge of 0·156 in. The sheet is manufactured by resistance welding which eliminates the excess weight of brazing or adhesive materials. The beads along the sides of the corrugation are said to double its crushing strength and improve other physical properties. Spacemetal is said to be 235 times stiffer and to carry twenty-three times the bending load of solid stainless steel of equal weight. North American Aviation Inc.

EMD 1112 for further information

Tantalum Bayonet Heaters

The use of tantalum for bayonet heaters is said to give a rate of heat transfer as much as eight times greater than that obtained with conventional bayonet heaters. The high ductility of tantalum is said to give excellent resistance to physical and thermal shock and its exceptional corrosion resistance means that extremely thin wall sections can be used with improvement in heat-transfer rate. The Pfaudler Co.

EMD 1113 for further information

Quartz Yarn

Quartz fibre yarns composed of high purity vitreous silica are now available and, compared to typical E glass, they have a high melting point (1,667 deg. C.), improved loss factor and a very much lower coefficient of thermal expansion. The yarns will withstand substantial loads at temperatures where glass fibres are softened. The high strength, high temperature and dimensional stability of quartz yarn allow a 15 per cent weight reduction to be made compared with E glass. General Electric Co.

EMD 1114 for further information

Energy Cartridges

These consist of compact spring components comprising an assembly of spring washers in series, in parallel or in parallel-series. They are assembled in stacks held together by a flexible outer covering or by a central pin passing through the washers. They are recommended where it is necessary to get high loads with relatively small deflection or to get a special load deflection curve. They are recommended as a shock absorber in machinery such as impact presses or for incorporation as die springs. They can also be used to exert a force at a low rate, that is, a very small increase in load in proportion to the increase in deflection, such as in clutches for drives. They can also be used to maintain reasonably constant pressure in spite of temperature variations such as in face-type seals. Associated Spring Corp.

EMD 1115 for further information

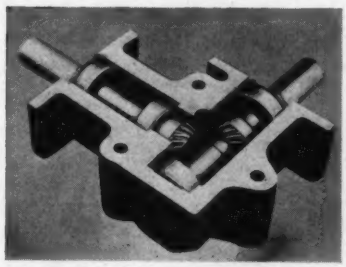
Silicone Sleeving

A new formulation of silicone rubber is said to produce the toughest, most flexible, most resistant and resilient unsupported tubing yet developed. It is said to withstand continuous operation from −85 deg. C. to +260 deg. C. and to be highly resistant to heat-ageing, never losing its flexibility. Known as Ben-Har 1258, the sleeving is available in standard wall thicknesses of 0·015 and 0·035 in. Bentley, Harris Manufacturing Co.

EMD 1116 for further information

Right Angle Power Units

New models and several design improvements have been announced for



right angle power-transfer units. Increased life, ability to handle higher load capacities and quieter operation are said to have been made possible by standardisation on hardened steel spiral gears. The new units are also equipped with non-magnetic, stainless-steel shafts and double-sealed, hardened and ground ball bearings.

Other features of the new line include a choice of two and three shaft extensions, a light, compact, completely enclosed 356 aluminium alloy housing designed for maximum strength and heat dissipation, and a choice of four or five mounting positions.

These right angle units are available in two-way or three-way designs. Each of these general types has optional 1:1 or 2:1 ratios. Ratings are from ¼ h.p. to 2 h.p. Crown Gear div. of Harrison & Richardson Inc.

EMD 1117 for further information

Miniature Insulator

A new miniature compression-mounted feed-through insulator, designated No. CF-408-X87, has been developed using

p.t.f.e. body construction, and is said to exhibit excellent electrical characteristics for high-frequency, high-temperature and high-voltage circuits.

Two advantages to electronics manufacturers are the fact that the insulator is permanently attached to a chassis by merely compressing it into a mounting hole, and wiring time is reduced by a hole lengthwise through the terminal, allowing rapid wire insertion and soldering. The insulator is self-fastening and requires no additional hardware, thus substantially reducing assembly time and costs.

The outstanding properties of p.t.f.e. are said to permit a press fit without breakage and to eliminate danger of loosening caused by mechanical shock or vibration. The brass terminal is hot tin dipped and other finishes are available. Fluorocarbon Products Inc.

EMD 1118 for further information

Beryllia Ceramic

Berlox pure beryllium oxide is said to have very high thermal conductivity and high electrical resistivity coupled with extremely high thermal shock resistance. It is produced in the form of rods, tubes and discs, boats and crucibles and is of particular interest for high-temperature operation because of its high melting point, i.e., 2,570 deg. C. National Beryllia Corp.

EMD 1119 for further information

Rubber-to-rubber Bonding

A unique adhesive for heat bonding dissimilar unvulcanised elastomers is now available. Known as EX-B150-1, it is said to be the first successful adhesive to give rubber-to-rubber bonds between elastomer combinations previously thought impossible to join.

This development introduces new advantages and economies where the properties of two elastomers are combined into a superior finished product. Typical applications of this type include conveyor belt covers to bodies, wire and cable jackets to insulation, hose covers, roll covers and multilayer gloves.

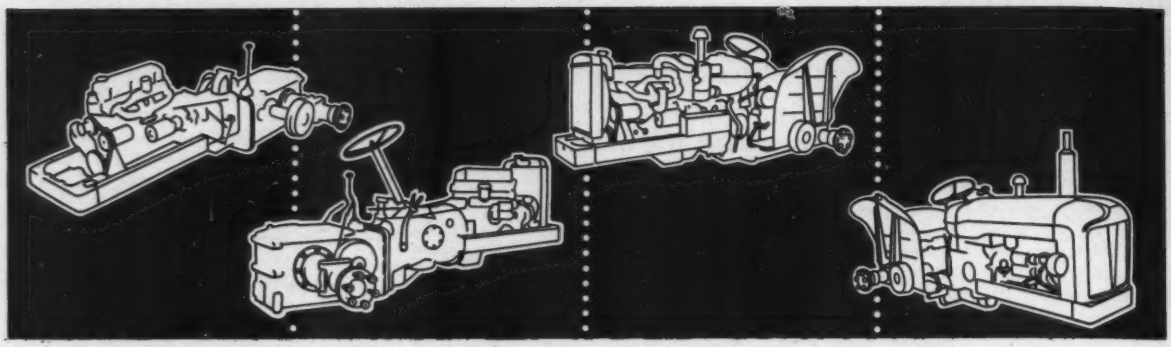
The adhesive is claimed to produce rubber-tearing bonds which resist ageing and retain high-strength after prolonged flexing. It fills a particular need when one of the stocks involved is based upon butyl rubber. In many cases it will produce good bonds even if one stock is cured, as in a CV cable jacketing operation. When used with a primer, it bonds rubber stocks to many other substrates such as plastics or metals. Lord Manufacturing Co.

EMD 1120 for further information

Insulating Material

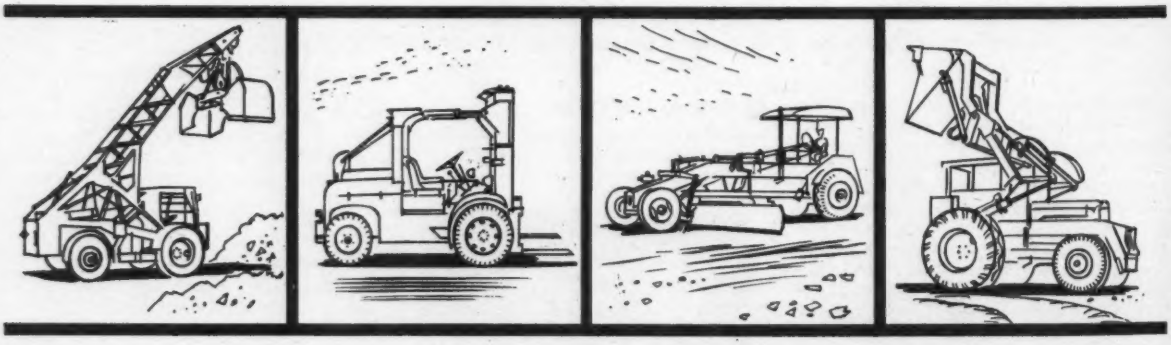
A form of irradiated polyolefin with a dielectric strength of 1,000 v.p.m. and a dissipation factor of 0·0005 is claimed to retain excellent form stability to beyond 300 deg. C. It will not melt, it is said, at any temperature and remains hard and tough with little or no cold flow at low temperatures. The material is available as a powder or as bars, rods and sheets for ready machining. Enflo Corp.

EMD 1121 for further information



Designers looking for a 'sales plus' specify **Fordson Power**

They look for Fordson Power because it gives equipment the stamp of reliability, ensures high output at low cost, and because it has the backing of the Ford world-wide service and spares organisation. There are Fordson Industrial Units in the 30-40 and 40-50 b.h.p. classes, in more than 100 different assemblies. Fit Fordson and you get all the benefits of quality mass-production from Ford's famous Dagenham factory, the biggest producer of mobile power units. Fit Fordson, the unit tailor-made to your requirements. Send for detailed specifications today.



Wise buyers insist on **Fordson Power**

INDUSTRIAL SALES DEPARTMENT, TRACTOR DIVISION
FORD MOTOR COMPANY LIMITED, DAGENHAM, ESSEX

News of Industry

Britain plans to put on the most striking demonstration of its advances in science, technology and engineering ever staged abroad, as part of the **British Exhibition** which will be held in New York in June next year.

Individual and group exhibits will feature both light and heavy engineering products, electrical, mechanical and chemical engineering goods, machinery and equipment for all industrial purposes, plastics, chemicals, electronics, automation and instrumentation.

Marking the twenty-fifth anniversary of the company, **Ciba (A.R.L.) Ltd.** recently opened at Duxford an automatic plant for the production of Araldite resins, together with new research laboratories and other premises. The plant, providing a working area on four floors of 16,300 sq. ft., is controlled by three men per shift.

Timed for introduction with the first International Transistor Exhibition in London, a useful new guide to transistors and associated semi-conductor devices has been published (at 6s. post free) by **Heywood & Co.** under the title *The Transistor Era*. Intended to be a standard course of reference to products of this kind in the U.K., it does, however, also include manufacturers in other countries.

The **Goodyear Tyre & Rubber Co. (G.B.) Ltd.** has announced an agreement with **Electro Hydraulics Ltd.**, whereby the latter company produces all Goodyear-designed wheel, brake and associated hydraulic equipment. Goodyear keep responsibility for design, modification and repair of all equipment except hydraulic brake controls, which will be designed and made by Electro Hydraulics.

New laboratories for the **Coil Spring Federation Research Association** being completed in Sheffield this month are among the most comprehensive of their kind in the world. They will enable research to be carried out on springs made from the finest wires to bars of up to 2 in. diameter. In addition, research will be possible on materials in wire and strip form. Metallurgical research will also be undertaken on a very wide range of ferrous and non-ferrous alloys.

The **Central Electricity Generating Board** is to establish a new research centre adjacent to the Berkeley nuclear power station in Gloucestershire. It will consist of engineering, physics, metallurgy and chemistry laboratories, some of which will enable studies to be made of intensely radio-active materials or for work with materials having no radio-activity but giving rise to a toxic hazard. Other work envisaged are heat transfer and fluid flow problems, some unit processes in chemical engineering, the development of complicated structures and mechanisms for the study of engineering designs and materials and the study of stresses in massive structures. One function of the laboratory will be to give a constant appraisal of the state of materials used in the reactors.

Under an agreement recently signed, **Birfield Tools Ltd.** are now sole licensees in the U.K. for the sale, installation and servicing of machine tools produced by the Hofmann Organisation of Western Germany.

The **Pneumatics and Hydraulics for Industry** Exhibition and Convention, which was to have been held in October at Alexandra Palace, is to be amalgamated with the First International Compressed Air and Hydraulics Exhibition, scheduled for Olympia in April next year. This follows talks between the organisers, who have agreed that only the Olympia exhibition will now take place.

The **Timber Development Association** announce a bursary in timber engineering tenable from October, 1959, at an approved British university. Candidates must hold a degree in engineering or mechanical sciences and have a good knowledge of the theory of structures.

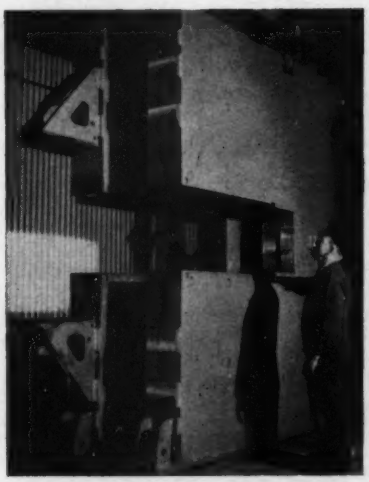
Leyland Motors Ltd. have opened a new manufacturing section to deal solely with glass fibre material. Initially, it is fully occupied with the production of glass fibre cowls which cover the power pack on the Atlantean rear-engined bus. Research and development is also being carried out on other parts which are at present constructed of sheet metal.

A recent film produced by **Jessop-Saville (Small Tools) Ltd.** with the title of *Cutanit Cemented Carbides* shows the way in which this material is produced and also some of its major applications, particularly for cutting tools. Other uses of interest are as thread guides in the textile industry and accurate moulds for producing high quality refractory bricks. A more recent application depicted is in the claws of film projectors, where the wear rate (as much as 90,000 contacts for a twenty-minute film) can be extremely high.

Applicants for U.K. patents last year reached the record figure of 42,000. This total, given by the **Patents Office** in its annual report, accounts for some 24,000 from inventors in this country, the remainder being received principally from the U.S.A. (7,000), Germany (4,000), France (1,600) and Switzerland (1,300). Applications from Japan rose from 152 to 200.

The chairman of the British national committee of the **International Congress on Combustion Engines** (CIMAC), Mr. W. K. G. Allen, said at the fourth general meeting of supporters that he hoped Britain would be able to act as host for a CIMAC congress in the not-too-distant future. This would depend to a large extent on support from British industries. He stressed the importance of the work of the British national committee in keeping alive the interest in overseas activities and in maintaining this country's prestige. The results of this work can be judged by the fact that at the forthcoming congress at Wiesbaden 160 British delegates will attend and the discussion will include ten British papers, the largest contribution made by any country.

A 7,000-ton core of an electromagnet is now being built by **Joseph Sankey & Sons Ltd.** for the National Institute for Research in Nuclear Science, which has just celebrated the first anniversary of its Royal Charter. An outstanding engineering feat, the complete magnet core will be 160 ft. in diameter, accurate in parts to 0·005 in. To simplify transportation, it is being produced in 336 sectors, at the rate of one a day, each sector weighing nearly 20 tons and tapered to one half of one degree at the rear to ensure perfect fit. Each magnet sector is 10 ft. 5 in. × 9 ft. 3 in. × 12¼ in. thick, made up from forty-five silicon steel plates. The sectors form the largest component part of the 7-GeV. proton synchrotron being built at Harwell for fundamental research in nuclear physics.

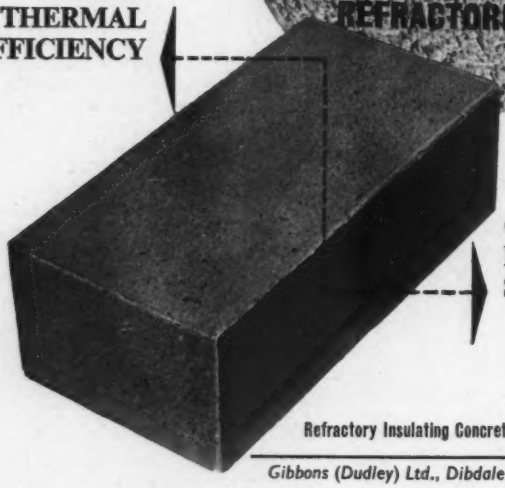


These are two of the 20-ton magnet sectors making up the core of the 7-GeV. proton synchrotron now being built at Harwell. (See story above.)

The recent **Foundry Exhibition** at Birmingham was so successful that it may become a regular event planned on an international basis. The display, sponsored by the Foundry Trades Equipment and Supplies Association, was the first post-war venture of its kind.

The new Austin Shamrock car, which is designed expressly for the Atlantic market, has a body made entirely of resinated polyester/glass supplied by British Resin Products Ltd. A double skin technique has been used for the doors, boot area and engine bay, providing optimum rigidity. It is anticipated that a plastics honeycomb construction will eventually be used for the hard top. Plant has been laid down in Ireland for initial production of 3,000 a year, expanding to 10,000, using the hand lay-up process.

GIBBONS "H·T 1" INSULATING REFRACTORIES



In producing the "H.T 1" brick efforts have been concentrated on obtaining a balance between the inter-related properties of thermal efficiency and mechanical strength. Research and development work has resulted in the evolution of entirely new manufacturing methods whereby high insulating value and low heat storage capacity have been attained with an exceptionally high mechanical strength.

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